A

MANUAL OF CHEMISTRY;

CONTAINING

A CONDENSED VIEW OF THE PRESENT STATE OF
THE SCIENCE, WITH COPIOUS REFERENCES
TO MORE EXTENSIVE TREATISES,
ORIGINAL PAPERS, &c.

INTENDED AS A TEXT-BOOK FOR

MEDICAL SCHOOLS, COLLEGES AND ACADEMIES.

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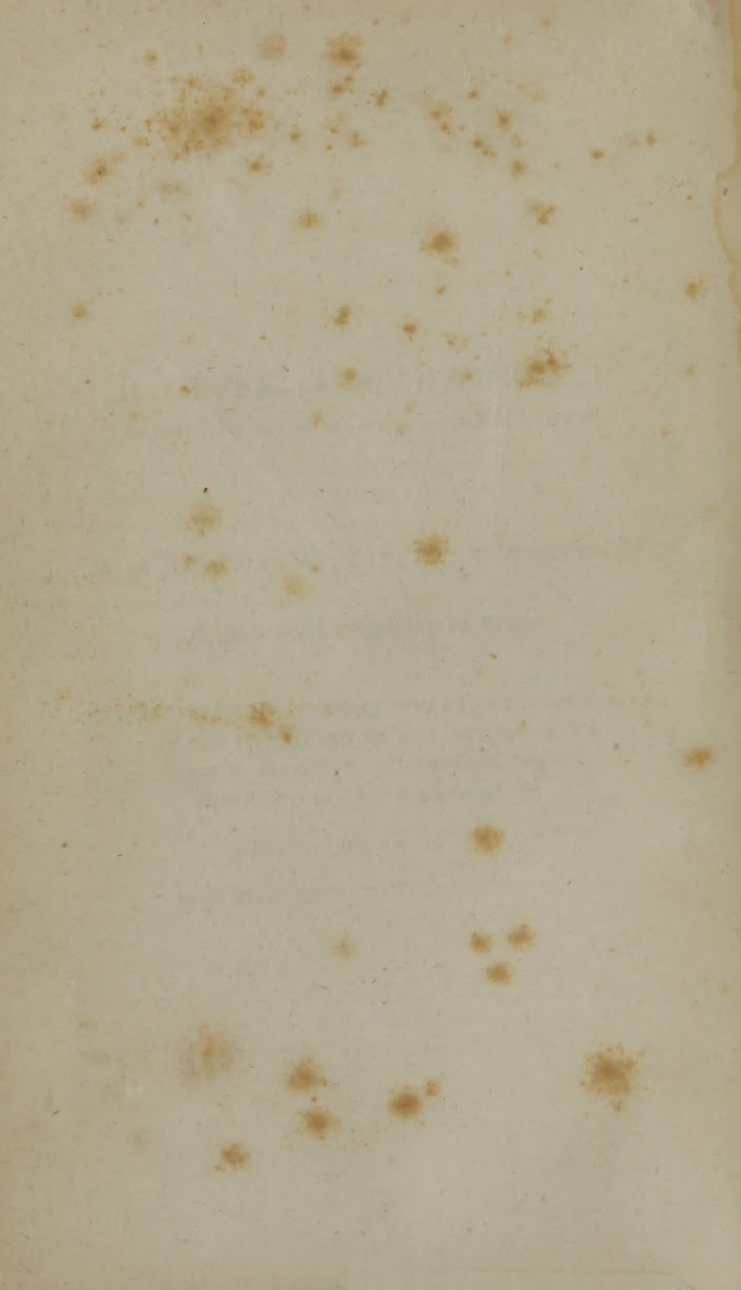
PREFACE

TO THE THIRD EDITION.

In preparing the Third Edition of this Manual, I have adhered to the original plan of the work, which was to set forth in a concise and perspicuous manner the principal facts of the science to which it is devoted; and at the same time to furnish the student with such references to other works and memoirs as would give direction to his enquiries in cases of doubt or difficulty.

In this as in the preceding editions, I have constantly consulted the elaborate treatises of Berzelius, Thenard, Thomson, Henry, Brande and Turner. I should state, however, that the work of the late Dr. Turner has been used more freely than any other, and may in some respects be considered the basis of the present Manual.

The method of arranging the subjects is essentially that proposed some years since by Professor Brande; which I have adopted from the conviction, that although not entirely free from objections, it is upon the whole more easily acquired by the student, than any which to my knowledge has hitherto been followed.

In the description of individual substances, brevity has been consulted as far as was consistent and I have in many instances employed the style usually pursued in Natural History. The atomic numbers and symbols introduced into the last edition have been continued with little alteration in this; and in the case of the simple bodies and of the more important compound ones, they are so placed at the head of each article that their meaning will at once be understood and cannot occasion the least embarrassment to the student. Thus, B is the symbol for Boron, and 8 is its atomic number; Ba. is the symbol for Barium, and 68·7, its atomic number. When bodies combine atom to atom, as in the case of Protoxide of Nitrogen, the symbol is $O+N$, and the atomic number of this compound is $O8+N\ 14=22$; but when more than one atom of an element is

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contained in a compound, a figure indicates the number of atoms. Thus $5O+N$ denotes Nitric Acid and indicates that it consists of 5 atoms of Oxygen combined with one atom of Nitrogen. The atomic number of this compound is $5O+1N=54$

In those cases where the symbol is complex abbreviations are sometimes employed. Thus, Aq. for water, and Ac. for acid, will be occasionally noticed in the descriptions of the salts.

The improvements in the present edition consist in the introduction of many interesting facts discovered within the last four years, which are inserted in their proper places: the descriptions and wood cuts of the most useful articles of apparatus, some of which will be found in the body of the work, while others, with definitions of chemical terms, and tables of atomic weights, of specific gravities, and of weights and measures, constitute an appendix. The materials for the latter additions have been chiefly drawn from the last volume of Berzelius' Traité de Chimie, Faraday's work on Chemical Manipulation, and Reid's Practical Chemistry.

It only remains for me to acknowledge the important aid which in the preparation of this work and in its subsequent revisions, I have received from my brother Dr. T. Romeyn Beck ; and to express my obligations to my brother Dr. John B. Beck for the revision and correction of a part of these sheets as they passed through the press.

University of the City of New-York,
    September, 1838.

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MANUAL OF CHEMISTRY.

DEFINITION OF CHEMISTRY.

CHEMISTRY* has been variously defined. By Dr. Black it was denominated "the science of heat and mixture." Modern chemists, however, have given it a wider range. Thomson calls it the science which treats of those events and changes in natural bodies, which are not accompanied by sensible motions.— *Syst. of Chem.* i. 18. Brande considers it "the object of chemistry to investigate all changes in the constitution of matter, whether effected by heat, mixture or other means."—*Man. of Chem.* 1. According to Berzelius, "chemistry is the science which makes us acquainted with the composition of bodies and with the manner in which they act upon each other."— *Trait. de Chim.* i. 31.

Chemistry borders closely in many instances upon Natural Philosophy ; but the distinction can be easily drawn.

It is the office of natural philosophy to investigate the sensible motions of all bodies ; whereas chemistry studies the constitution and qualites of these bodies.

The natural philosopher contemplates whole masses and ascertains their properties ; while the chemist notices the operations of their particles, observes their reciprocal actions and seeks to discover all the changes that may occur.

Thus in examining our atmosphere, when studied as a whole, its weight, pressure, density and elasticity, are subjects falling within the province of natural philosophy ; but when we endeavour to discover the elements of which this air is composed, the changes which it undergoes, by heat or combination, and the phenomena which attend these changes, we are within the boundaries of chemistry.

The business of the chemist, therefore, is to interrogate nature, and thus to make himself acquainted with the ultimate constitution of bodies. When this is effected, he is furnished with the means of imitating her in some of her most interesting operations, and thus in many instances, of contributing largely to individual as well as to national wealth and prosperity.

Chemistry is divided into—

I. The general forces, or powers productive of chemical phenomena and the laws which govern them ; or the general theory of the science.

II. The particular effects which are produced in different bodies by

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* The term chemistry is probably derived from the Greek word *Chemia,* originally applied to the art of making gold and silver. The Arabians by prefixing the article gave it the name of *Alchemy.—Thomson's History of Chemistry.*

the agency of these general powers; or the chemical history of individual substances.

The general powers, or as they are sometimes called, general properties of matter, or imponderable substances, are

<div style="text-align:center">

ATTRACTION.
HEAT.
LIGHT.
ELECTRICITY.
MAGNETISM.

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CHAPTER I.

ATTRACTION.

The term attraction is employed to express that unknown principle which causes distant bodies to approach each other, and to resist a separation with some degree of force.

Attraction may be,

I. *Remote ;* when it acts on masses of matter at sensible distances; as in gravitation, electricity, and magnetism.

II. *Contiguous ;* when it acts on masses of matter at insensible distances; as in cohesion and in chemical affinity.

Contiguous attraction is of two kinds, viz. : homogeneous and heterogeneous, or cohesion and affinity. The former takes place between bodies of the same nature, and the latter between those which are different.

SECTION I.

COHESION.

SYNONYMES. *Attraction of Aggregation—Cohesive Affinity—Corpuscular, or Molecular Attraction—Homogeneous Affinity.*

Cohesion may be defined to be that force or power by which particles or atoms of the same kind are brought into contact and retained in that situation.

Cohesion is exerted in different bodies with different degrees of force. In solids, its force is exerted with the greatest intensity ; in liquids, it acts with much less energy ; and in æriform bodies it is doubtful whether it exist at all. Thus water in a solid state has considerable cohesion, which is much diminished when it becomes liquid, and is entirely destroyed as soon as it is changed into vapour.

The force of cohesion in solid bodies which is denominated *tenacity*, is measured by the weight necessary to break them, or rather to pull them asunder. Heat is excited at the same time, a good illustration of which occurs in the process of wire drawing. [An abstract of Mr. Rennie's elaborate experiments on the cohesive force of various solids will be found in *Ure's Chem. Dictionary*.]

In liquids the force of cohesion is demonstrated by the spherical figure which they assume when suffered to form drops. The drop is spherical, because each particle of the fluid exerts an equal force in every direction, drawing other particles towards it on every side, as far as its power extends. To the same cause is owing the property possessed by all liquids of remaining heaped up above the brims of the vessels which contain them.

Other examples of cohesion.

1. Similar portions being cut off with a clean knife from two leaden bullets and the fresh surfaces being brought into contact with a slight turning pressure, the bullets cohere, almost as if they had been originally cast together.

2. Fresh cut surfaces of India rubber adhere in a similar manner.

3. Two pieces of perfectly smooth glass or marble laid upon each other adhere with great force.

It has been supposed that in some of the above cases the attractive force is confined to the surfaces of the masses, and it has been called *adhesion*. Mr. Ruhland has given a table exhibiting the weights which were found necessary to separate equal surfaces of different bodies from the same liquids. [*Gorham's Chem.* i. 6. *Ann. of Phil.* vii. 20.] Dr. Thomson considers adhesion as exhibiting the characteristic marks of chemical affinity and as affording a particular case of the action of that power.

Cohesion is weakened by the following causes :

I. *By heat.* When a fusible body is exposed to the influence of heat, its volume is at first augmented, and this increase of bulk is in consequence of the separation to a certain degree of its constituents. Cohesion is thus lessened, though not destroyed ; and hence if heated zinc be struck with a hammer, much less force will be required to disintegrate it, than if it were at the ordinary temperature of the air. If the heat be continued, the particles of the metal will be so far removed from each other, as to allow of free motion, and it will become liquid. By raising the heat still higher, while the metal is not in contact with the air, all cohesion will be removed and it will be resolved into vapour or an elastic fluid.

II. *By mechanical violence.* Under this head may be arranged several processes which are highly useful in the laboratory, as—

Pulverization and trituration ; by which substances are reduced to powder, generally performed by means of pestles and mortars.

Levigation ; a process similar to trituration, except that the rubbing is assisted by the addition of a liquid in which the solid matter under operation is not soluble.

Granulation ; effected either by pouring the substance while in fusion into cold water, or by agitating it in a box.

Sifting ; employed for the purpose of obtaining bodies in powder of an equal degree of fineness throughout, performed by instruments termed *sieves.*

III. *By the influence of a more powerful attraction.* Thus if a mass of lime be immersed in vinegar, it gradually lessens and finally disappears. Here an attractive force has been introduced which is superior to the

attraction of the particles of lime for each other, and consequently they are separated.

The effects of the exertion of cohesion are,

1. To unite the particles of bodies in a confused manner, without any regularity of form.

2. To bring them together in a determinate mode so as to form regular geometrical figures or crystals. The latter is the most frequent.

CRYSTALLIZATION.

When we diminish in any manner the cohesion of a solid body so as to render it liquid or gaseous and afterwards remove the cause of this change, the body returns to its former state and the molecules arrange themselves in a determinate manner, or in the form of crystals. Hence when a body passes from a gaseous or liquid state to that of a solid, it crystallizes ; but if this passage be too rapid, the crystallization will be confused.

The most common agents employed to crystallize bodies are *water and heat ; alcohol* is also sometimes made use of in certain analyses.

I. *Water.* This agent is employed in two ways, viz.

a. To dissolve the body by the aid of heat and then to allow the solution to cool. In this case it will generally be only necessary to continue the process of evaporation until a drop of the solution when placed upon a cold body shows a tendency to crystallize ; or at least until a film or *pellicle* appears on its surface. This proves that the attraction of the saline particles for each other is becoming superior to their attraction for the water. In this case, crystallization takes place because hot water generally dissolves a greater quantity of salt than cold water, and when it has become saturated a portion is necessarily deposited as the water cools. There are, however, a few exceptions to the law that salts are more soluble in hot than in cold water, and Mr. Graham suggests that the efflorescent salts generally belong to this class.—*Phil. Mag. and Ann.* i. 7.

b. To leave the cold solution to spontaneous evaporation. In this case the water by evaporation is brought to the point at which it is unable to hold the salt in solution.

In both of the above cases, crystals generally retain a portion of water, which is termed the *water of crystallization*, and the salts containing it are denominated *hydrous salts.* These salts when heated liquify and undergo a process which is called *watery fusion.* Alum offers a familiar example.

In a few cases, however, salts do not retain any water of crystallization and they are then termed *anhydrous salts.*

Salts, in crystallizing, frequently enclose mechanically within their texture particles of water, by the expansion of which, when heated, the salt is burst with a crackling noise into smaller fragments. This phenomenon is known by the name of *decrepitation* ; and it is observed to be most powerful in those crystals which contain no water of crystallization ; as the nitrates of baryta and of lead.

Some salts part with their water of crystallization by a simple exposure to dry air, when they are said to *effloresce* ; but there are other salts which *deliquesce* or attract water from the atmosphere. Car-

bonate of potash is a deliquescent salt ; carbonate of soda an effloresscent one. [For a table of the action of atmospheric air, on some of the most common salts, see *Parkes' Chem. Catechism*, 231, 8th ed.]

II. *Heat.* There are two methods of employing this agent, viz.

a. To expose the body to heat until it has melted, then to let it cool slowly and without agitation, till a crust has formed on its surface, to pierce this crust and decant the liquid contained in the interior. We then obtain the outer portion in the form of a solid crystalline bed, sometimes resembling a geode. This effect can be finely exhibited by treating in such a manner sulphur, or lead, bismuth and some other of the semi-crystalline metals.

b To reduce the body to a state of vapour and to condense it gradually. This however, is not always practicable, because few of the solids can be volatilized. The process is generally called *Sublimation.*

Exp. Put powder of corrosive sublimate or arsenic in a dry flask, obstruct the mouth slightly and apply heat. The vapour rises and forms crystals in the upper part. More heat is required in the case of arsenic than in that of corrosive sublimate.

III. *Alcohol.* This is generally employed by applying heat and then allowing the solution to cool as above. The great utility of this agent depends upon the fact, that a few salts only are soluble in it. Hence it is often made use of to separate such salts from others with which they may be combined. It is scarcely necessary to observe that in such cases the purest alcohol must be employed. [For a table of substances soluble in alcohol, see *Henry's Chem.* 11th ed. ii. 653.]

Several circumstances affecting the process of crystallization deserve to be noticed. Among these are,

1. *Rapidity of evaporation.* When the heat is high and the evaporation very rapid, the crystallization is confused.

2. *The access of atmospheric air.* This under certain cicumstances produces instant crystallization in some saline solutions. Those which are the most remarkable on this account are carbonate and sulphate of soda. Hot saturated solutions of these salts in well corked phials may be cooled down without the deposition of any crystals, but as soon as the corks are withdrawn, crystals begin to form and at the same time the temperature rises. Dr. Thomson has satisfactorily proved that the water of crystallization of the salt which crystallizes, gives out its latent heat, and that this evolution is the cause of the increase of temperature observed. *— Ann. of Phil.* xix. 169.

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* The theory of this singular phenomenon has not yet been well settled.— That it does not depend on atmospheric pressure is proved by the fact that the solution may be cooled in open vessels without becoming solid, provided its surface be covered with a film of oil, as first shown by Gay Lussac ; and, as Dr. Turner states, that the experiment also succeeds without the use of oil by causing the air of the flask to communicate with the atmosphere by means of a moderately narrow tube.

Mr. Graham supposes the effect of air to arise from a certain chemical action upon water. He has shown that gases which are more freely absorbed than atmospheric air, act more rapidly in producing crystallization. And it would seem from his experiments that the rapidity of crystallization, occasioned by the con-

3. *The nature of the liquor in which the crystals are formed.* Dr. Wohler has ascertained that this often influences the fundamental or primitive forms of crystals. Thus he says that when a small portion of solution of sulphate of iron is poured into a solution of alum and the whole allowed to crystallize, the sulphate of iron assumes the octahedral form of the alum, although these octahedral crystals contain scarcely a trace of alum.—*Edin. New Phil. Jour.* i. 189.

4. *The immersion of some foreign body into the saline solution.* This serves as a nucleus or attracting point around which the particles as they are deposited may be attached. Hence many of the salts are found concreted around sticks or twigs, and the crystals of sugar are arranged around threads. A crystal of the same kind as that held in solution also answers the purpose.

5. *Light.* Of this, instances are observed in the bottles of camphor placed in druggists' windows, where the crystals are always most copious on the side exposed to the light. Chaptal found that by using a solution of a metallic salt, and shading the greater part of the vessel with black silk, capillary crystals shoot up the uncovered sides, and that the extent of the exposed part is distinctly marked by the limit of crystallization. The phenomenon termed *saline vegetation,* consisting in the creeping of the salt around the edge of the vessel, is also referred by Chaptal to the influence of light. For the perfect success of this experiment, the edges of the vessel should be smeared with oil.

6. *Electricity.* It has been repeatedly remarked that saline solutions which have not yielded crystals, after having been sufficiently concentrated and left undisturbed for several days, have suddenly deposited an abundant crop, during, or immediately after a thunder storm. Dr. Ure has shown that negative electricity facilitates, and positive electricity retards the formation of crystals.—*Brande's Jour.* iv. 106.

Crystallographers have observed that certain crystalline forms are peculiar to certain substances. Thus, calcareous spar crystallizes in rhombs, fluor spar in cubes, and quartz in six-sided pyramids; and these forms are so far peculiar to those substances, that fluor spar is never found in rhombs or six-sided pyramids, nor does calcareous spar or quartz ever occur in cubes. Crystalline form may, therefore, serve as a ground of distinction between different substances. It is

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tact of gaseous matter, is proportional to the degree of its affinity for water. Upon this principle also, he accounts for the fact that solutions of sulphate of soda which have not been boiled are less affected by exposure to the air than well boiled solutions ; for the former still retain most of their air, and do not absorb air so eagerly on exposure as solutions which have been boiled.—*Phil. Mag. and Annals,* iv. 215.

On the other hand, Dr. H. Ogden contends that the access of air is not necessary to the process of crystallization. He asserts that it often occurs when the vessel is closed, by mere agitation, without opening it, (a fact which I have also observed,) and to this he ascribes the results of Mr. Graham. He also shows that this peculiar property of resisting crystallization is not confined to any genus of salts in particular, and he enumerates several alkaline, earthy and metallic salts which will exhibit it. Among these are the sulphate, carbonate, acetate, and phosphate of soda, the tartrate of potash and soda, ferrocyanate of potash, sulphate of magnesia, the muriates of lime and barytes and the sulphate of copper.—*New Edin. Jour.* xiii. 309.

accordingly employed by mineralogists for distinguishing one mineral species from another; and it is very serviceable to the chemist as affording a physical character for salts. A notice for this subject therefore should form a part of every treatise on chemistry.

The surfaces which limit the figure of crystals are called the *planes* or *faces*, and are generally flat. The lines formed by the junction of two planes, are called *edges*, and the angle formed by two such edges is a *plane angle*. A *solid angle* is the point formed by the meeting of at least three planes. The planes which terminate a prism are called *terminal planes;* those at the sides *lateral planes;* the face on which a crystal is supposed to stand is called a *base*. When the end of a crystal is formed by two planes inclined to each other like the roof of a house, it is said to be *culminated;* if three or more planes meeting in a solid angle, terminate the prism, they form a pyramid which is called the *summit;* the planes which form the summit are called *acuminating planes*, and the edges produced by their junction, *edges of the pyramid*. When an edge or solid angle is cut off and replaced by a single new face, it is said to be *truncated;* if by two or more new faces, it is *bevelled*. A very short prism is called a *table*.

The forms of crystals are very various. They are divided by crystallographers into what are called *primitive, primary, derivative,* or *fundamental* forms, and into *secondary* or *derived* forms.

The number of primary forms is differently stated by different authors, according to the system which they adopt. The most simple, however, is that which reduces these forms to the following, viz.

1. The cube.

2. The tetrahedron.

3. The octahedron.

4. The six-sided prism.

5. The rhombic dodecahedron.

6. The dodecahedron with isosceles triangular faces.

7. The rhomb.

These primitive forms by further mechanical analysis may be reduced to three integral elements.

1. The parallelopiped, or simplest solid having six surfaces, parallel, two and two.

2. The triangular or simplest prism, bounded by five surfaces.

3. The tetrahedron or simplest pyramid, bounded by four surfaces.

The *secondary* forms are supposed to arise from decrements of particles taking place on different edges and angles of its primitive forms. Thus a cube, having a series of decreasing layers of cubic particles upon each of its six faces, will become a dodecahedron, if the decrement be upon the edges; but an octahedron, if upon the angles; and by irregular, intermediate, and mixed decrements, an infinite variety of secondary forms would ensue.

There are some appearances in crystallography to which the above explanation will not apply. A slice of fluor spar, for instance, obtained by making two successive and parallel sections, may be divided into acute rhomboids; but these are not the primitive forms of the spar, because by the removal of a tetrahedron from each extremity of the rhomboid, an octahedron is obtained. Thus, as the whole mass of fluor may be divided into tetrahedrons and octahedrons, it becomes a question which of these forms is to be called primitive, especially as neither of them can fill space without leaving vacuities, a structure not adapted to form the basis of a permanent crystal. To obviate this difficulty, Dr. Wollaston suggested that the integrant particles of all crystals might be considered as spheres or spheroids, which by their mutual attraction have assumed that arrangement which brings them as near as possible to each other; and this view of the subject has been confirmed by the experiments of Mr. Daniell. [*Wollaston, in Phil. Trans.* 1813. *Daniell, in Brande's Jour.* i. 24.] But although the preponderance of evidence is rather on the side of the spherical form of atoms, this opinion is attended with difficulties which in the present state of our knowledge cannot be obviated. Such are some of the facts developed by Isomorphism.—*See Thomson's Inorganic Chem.* i. 16.

The primitive forms of crystals can be ascertained—1st, by mechanical division or cleavage; and 2d, by the action of fluid menstrua. For our knowledge of the latter we are wholly indebted to Mr. Daniell; and the fact is well shown by plunging into a tumbler full of cold

water, a shapeless mass of alum, the surface of which becomes in a few days, eaten and carved out into a variety of regular crystalline forms.

The process called *cleavage* consists in separating thin layers or slices from the sides, edges or angles of a crystallized substance in a given direction. Many crystallized substances are very obviously composed of thin plates or laminæ, which by a careful operation may be separated from each other, without presenting the appearance of a fracture. The planes in which these laminæ are applied to each other, are called the *natural joints* of a crystal. The direction in which it may be cleaved is called the *direction* of *cleavage*. Sometimes a crystal is cleavable only in one direction, and it is then said to have a *single* cleavage. Others may be cleaved in two, three, four or more directions, and are said to have a *double, treble, fourfold* cleavage, and so on according to their number.

It was at one time supposed that substances of different composition never assumed precisely the same primitive form. But the researches of Professor Mitscherlich have proved, that certain substances are capable of being substituted for each other in combination without influencing the crystalline form of the compound. This discovery has led to the formation of groups, each comprehending substances which crystallize in the same manner, and which are hence said to be *isomorphous*. One of the most instructive of these groups includes the salts of arsenic and of the phosphoric acid. Thus the neutral phosphate and biphosphate of ammonia correspond to the arseniate and biarseniate of ammonia; and the biphosphate and biarseniate of potash have the same form. Indeed each arseniate has a corresponding phosphate, having the same form, the same number of equivalents of acid, alkali and water of crystallization, and differing in fact in nothing except that one series contains arsenic and the other an equivalent quantity of phosphorus. Several other similar groups occur, and while their study is of great importance to the chemist, their existence should serve as a caution to the mineralogist, not to place exclusive reliance on crystallographic character.

In some instances certain groups of crystals approximate in their forms without becoming identical. To this approximation the term *plesiomorphism*, has been applied.—An illustration occurs in the sulphates of strontia and baryta, the primary forms of both salts are rhombic prisms, very similar to each other; but on measuring the inclination of corresponding sides in each prism, the difference is found to exceed two degrees. The scope of this work forbids a more detailed view of these subjects, and I would therefore refer those who are desirous of a full account of the present state of our knowledge upon the subject of isomorphism, and the allied branches of enquiry, to *Mr. J. F. W. Johnston's Report on Chemistry, made in* 1832, *to the British Association for the advancement of Science.*

It is of great importance in the examination of crystals to measure their angles with precision; for this purpose an instrument has been invented, called a *goniometer*, of which there are two kinds, the *common* and the *reflective.*

The reflective goniometer, invented by Dr. Wollaston, is the most useful of these instruments. It enables us to determine the angles even of minute crystals, with great accuracy: a ray of light reflected from the surface of the crystal being employed as radius, instead of the

surface itself.—See *Phillips' Introduction to Mineralogy*, and *Brande's Chemistry*.

REFERENCES—*On* Cohesion—*Muschenbroeck's Experiments on the cohesive force of solid bodies, in Thomson's Chem.* iii. 94. *On the means employed by the chemist to prepare the particles of bodies for chemical action, in Chaptal's Chem. applied to the Arts,* i. 51. *Boscovich's explanation of the phenomena of cohesion, in Thomson's Chem.* iii. 96. *Arnott's Physics.*

On Crystallography—*Hauy Traité de Cristallographie,* i. *Brooke's Introduction to Crystallography. Cleaveland's Mineralogy. Philip's Introduction to Mineralogy. Shepard's Mineralogy. Moh's Mineralogy,* i. *Leblanc's method of obtaining large artificial crystals, in Thomson's Chemistry,* iii. 98. *Some valuable directions for crystallizing salts are also to be found in the Encyclopædia Britannica,* iv. 443. *Remarks upon Daniell's theory of Crystals, Ann. of Phil.* xi. 125, 129. 287.

SECTION II.

AFFINITY.

SYN. *Chemical Affinity — Chemical Attraction — Heterogeneous Attraction.*

If oil and water, or water, oil and mercury, be agitated together, they do not act on each other, but soon separate and exhibit their original characters; they do not combine and have no *affinity* for each other. But if olive oil and a solution of potassa be agitated together, they form a milky fluid in which neither of them is recognized; they unite and form a chemical combination; and bodies which unite chemically are said to have an affinity for each other, and those which do not unite under any circumstances in which they have been placed, are correctly said to have an affinity for each other.

Affinity is defined to be that force by which are united the particles or atoms of bodies of different kinds. Like cohesion, it is only effective at insensible distances; it is mutual and reciprocal between those bodies which it combines—thus A cannot be said to have an affinity for B, while B has none for A.

Affinity produces,

1. *In some cases a compound not materially altered in its properties.* Under this proposition, solution is usually offered as an illustration, though it may be doubted whether this is a good example of affinity.

Solution is an operation by which a solid body combines with a fluid in such a manner that the compound retains the form of a permanent and transparent fluid. In this case the fluid is termed a *menstruum*. Solution can easily be distinguished from a mere mechanical mixture or diffusion as follows:

Exp. Diffuse a quantity of magnesia in water, the mixture is turbid and finally the magnesia is deposited. If to the turbid mixture a few drops of nitric acid be added, it will become transparent, and the magnesia can no longer be separated by any mechanical process or by rest. The nitrate of magnesia is held in solution by the water.

Solution is promoted,

a. By diminishing the cohesion of the particles of the body to be dissolved.

Exp. Place a lump of marble in a wine glass, and a small quantity of the same, previously reduced to powder, in another; pour upon each, dilute muriatic acid; the powdered marble will dissolve much more rapidly than the lump.

b. By mechanical agitation.

Exp. Put a crystal of tartaric acid into a wine glass containing infusion of litmus or of cabbage. The acid if left at rest, produces only a slight effect in its immediate vicinity, but if the liquor be stirred, the whole will become red.

c. By heat.

There are a few exceptions to this statement which have already been adverted to. (p. 16.)

In most cases of solution there is a certain point at which the force of affinity between the solid and fluid will be balanced by the cohesion of the solid, and beyond which solution will not proceed : this point is called *saturation,* and the resulting compound a *saturated solution.*

2. *Affinity produces in most cases a compound whose properties differ essentially from those of the components.*

Exp. Burn phosphorus in oxygen gas or atmospheric air, the resulting compound is phosphoric acid.

Exp. Pass atmospheric air or oxygen gas into a vessel of nitric oxide; the resulting compound is nitrous acid.

Affinity sometimes also produces,

3. *A change of state.*

Exp. Two glass vessels, one filled with ammoniacal gas, and the other with muriatic acid gas, when brought into contact produce solid muriate of ammonia.

Exp. To a solution of muriate or nitrate of lime add sulphuric acid; solid sulphate of lime will be formed.

Exp. Crystals of sulphate of soda and nitrate of ammonia triturated together become a liquid.

Exp. Gunpowder, when exploded, is resolved into various gases.

4. *A change of colour.*

Exp. Add liquid ammonia to a solution of nitrate or sulphate of copper—a rich blue colour is produced. A few drops of sulphuric acid render it colourless.

Exp. Sulphate of copper and acetate of lead rubbed together in a mortar assume a green colour.

Exp. A few drops of tincture of galls added to a very dilute solution of sulphate of iron produce a deep black.

In each of these cases, the change of colour is owing to the formation of a new chemical compound.

5. *A change in specific gravity and temperature.*

Exp. Sulphuric acid and water when combined have the specific gravity of the compound greater than that of the mean.

Exp. Surround a phial with some tow and place a piece of phosphorus within the tow and against the phial. The phial being half full of water, add a small quantity of sulphuric acid; the heat produced will be sufficient to fire the phosphorus.

6. *Intense ignition.*

Exp. Add a few drops of sulphuric acid to a mixture of chlorate of potash and sugar.

Exp. Add sulphuric acid to phosphorus and chlorate of potash under water.

There are several circumstances which influence and modify the operation of affinity.

1. *A previous state of combination.* This generally diminishes, and often prevents chemical action.

2. *Cohesion.* This, as has been already remarked, often acts as an antagonist power to chemical affinity. Hence the utility of mechanical processes which diminish this force. Solid antimony is but slowly acted upon by chlorine gas, but when in the state of fine powder, it takes fire as soon as it touches the gas. Hence also liquidity favours chemical action, the cohesive power being comparatively so trifling as to present no appreciable barrier to affinity. There are, however, some instances in which two solids act chemically on each other.

3. *Caloric.* This has a very important influence over chemical action : sometimes increasing it, at other times destroying or subverting it. Thus bodies which unite at one temperature refuse to combine or remain combined at another temperature. Lead shavings do not decompose cold nitric acid, but when heat is applied, rapid decomposition ensues. An increase of temperature favours chemical action by its effect in overcoming the force of cohesion ; but this explanation is not of universal application.

4. *The electric state of bodies.* Those bodies which are in the same electric state do not combine, those in different electric states do combine. Indeed, so intimate is the connexion which subsists between electricity and chemical action, that they have been supposed by some to depend upon the same power. Hence the *Electro-Chemical Theory* of Davy, which will be more fully noticed hereafter.

5. *Specific gravity.* When two bodies have different specific gravities, they tend to separate. If their affinity is very feeble, they cannot be made to combine. Oil and water, and mercury and water, are familiar examples. The influence of specific gravity over chemical action is, however, quite limited.

6. *The intervention of a third body.* This sometimes increases and sometimes destroys chemical action. Oil and water are made to unite upon the addition of an alkali. Alcohol added to a saturated solution of sulphate of soda or nitrate of potassa combines with the water, and the crystallization of the salt instantly takes place. This has been

called *disposing or predisposing affinity*, which to say the least, is an extremely vague term.

7. *Mechanical action or compression.* This frequently modifies chemical action in a great degree, particularly in the case of gases and liquids. Thus water when under high pressure combines with a greater quantity of carbonic acid than when the pressure is less The compound of carbonic acid and lime, known under the name of chalk, may be decomposed by the simple application of an intense heat; but under strong pressure, a heat may be applied sufficient to melt the chalk without expelling the carbonic acid. It is this principle, (the influence of pressure in opposing chemical decomposition,) that is the foundation of Dr. Hutton's ingenious Theory of the Earth.—*Henry's Chem.* 11th ed. i. 65.

8. *Quantity of matter or mass.* The influence of quantity of matter over affinity appears to be now generally admitted. If one body A, unites with another body B, in several proportions, that compound will be the most difficult of decomposition which contains the smallest quantity of B. Of the three oxides of lead, for instance, the peroxide parts most easily with its oxygen by the action of caloric ; a higher temperature is required to decompose the deutoxide, and the protoxide will bear the strongest heat of our furnaces, without losing a particle of its oxygen.

The influence of quantity over chemical attraction may be further illustrated by the phenomena of solution. When equal weights of a soluble salt are added in succession to a given quantity of water, which is capable of dissolving almost the whole of the salt employed, the first portion of the salt will disappear more readily than the second, the second than the third, the third than the fourth, and so on. The affinity of the water for the saline substances diminishes with each addition, till at last it is weakened to such a degree as to be unable to overcome the cohesion of the salt. The process then ceases and a saturated solution is obtained.

Quantity of matter is employed advantageously in many chemical operations. If, for instance, a chemist is desirous of separating an acid from a metallic oxide, by means of the superior affinity of potassa for the former, he frequently uses rather more of the alkali than is sufficient for neutralizing the acid. He takes the precaution of employing an excess of alkali, in order the more effectually to bring every particle of the substance to be decomposed in contact with the decomposing agent.

But Berthollet has attributed a much greater influence to quantity of matter. His views, however, do not appear to be supported by facts.— *Berthollet Chem. Stat.* *Turner's Chem.* *Davy's Elements.*

Affinity is of two kinds—

1. SIMPLE.
2. ELECTIVE.

Simple affinity is the union of the constituent atoms of a compound without causing decomposition. It is sometimes also called *combination.* Thus the combustion of carbon in oxygen gas produces by the mere union of these two elements carbonic acid. So also sulphuric acid and potassa by mere combination form sulphate of potassa.

3

Elective affinity is of two kinds, *simple and compound, or single and double*.

An important law of affinity, and which indeed is the basis of almost all chemical theory, is that the same body has not the same force of affinity towards a number of others, but attracts them unequally.   Thus when sulphuric acid is added to a solution of nitrate of lime, (composed of nitric acid and lime,) the lime leaves the nitric acid and combines with the sulphuric, forming a sulphate of lime.   This is an example of what is termed in chemistry, a *simple decomposition*.   The lime in this case is considered as making an election of the sulphuric acid in preference to the nitric ; and this affinity has been called *single elective affinity*.   When one of the substances falls down in the state of powder, it is termed a *precipitate*.

Other illustrations of single elective affinity.

Exp.•Add sulphuric acid to muriate of soda, muriatic acid is disengaged and sulphate of soda remains.

Exp. To a solution of nitrate of silver, add mercury ; the nitric acid will in a short time leave the silver and combine with the mercury. To the nitrate of mercury thus formed, add lead, the nitric acid will leave the mercury and unite with the lead.   To this last add copper, and nitrate of copper will be produced.

Upon the discovery of this important law, it occurred to Geoffroy, a French chemist, that tables might be constructed, which should exhibit the relative forces of the attraction of any body towards others.   The substance, whose affinities are to be thus expressed, is merely placed at the head of a column separated from the rest by a horizontal line. Beneath this line are arranged the different substances for which it has any attraction, in an order corresponding with that of their respective forces of affinity ; the substance which it attracts most powerfully being placed nearest to it, and that for which it has the least affinity at the bottom of the column.   The following series exhibiting the affinities of sulphuric acid for the alkalies and alkaline earths, will serve as an example.

SULPHURIC ACID.

BARYTA,
STRONTIA,
POTASSA,
SODA,
LIME,
AMMONIA,
MAGNESIA.

Double elective affinity.   This kind of affinity takes place when two bodies, each consisting of two principles are presented to each other, and mutually exchange a principle of each ; by which means two new bodies or compounds, are produced, of a different nature from the original compounds.   In this case it frequently happens, that the compound of two principles cannot be destroyed, either by a third or a fourth separately applied ; whereas if this third and fourth be combined, and placed in contact with the former compound, a decomposition or change of

principles will ensue. Thus when limewater is added to a solution of sulphate of soda, no decomposition happens, because sulphuric acid attracts soda more strongly than it does lime. If nitric acid be applied to the same compound, still its principles remain undisturbed, because the sulphuric acid attracts soda more strongly than the nitric. But if lime and nitric acid previously combined, be mixed with the sulphate of soda, a double decomposition is effected and two new compounds are produced. These changes may be expressed by the following diagram, contrived by Bergman.

<div align="center">Nitrate of Soda.</div>

Sulphate of Soda.	{	Soda.	Nitric acid.	}	Nitrate of Lime.
		Sulphuric acid.	Lime.		
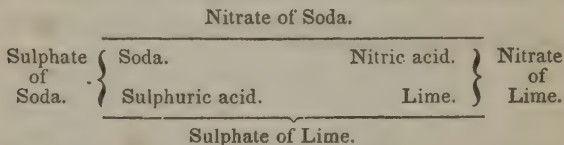
<div align="center">Sulphate of Lime.</div>

On the outside of the vertical brackets are placed the original compounds, (sulphate of soda and nitrate of lime,) above and below the horizontal lines, the new compounds produced, (*nitrate of soda and sulphate of lime*,) the upper line being straight indicates that the nitrate of soda remains in solution, the dip of the lower line, that the sulphate of lime is precipitated.

A piece of sheet lead immersed in a solution of sulphate of zinc produces no change, because the sulphuric acid has a stronger affinity for the zinc than for the lead. Neither does acetic acid produce any change. But when acetate of lead is added, two new compounds, viz. sulphate of lead and acetate of zinc are the result.

In the above cases, as in many others, we can easily explain the decompositions which take place. There are two distinct sets of affinities, one tending to prevent any change of composition, as between the sulphuric acid and the soda in the former case, and between the nitric acid and the lime ; termed by Kirwan the *quiescent affinities*. Another set tending to produce a decomposition, as between the nitric acid and the soda, and the sulphuric acid and the lime, are termed the *divellent affinities*, and which in this case are the most powerful. But other cases of double decomposition cannot be explained in this manner. As for instance, carbonate of baryta and sulphate of potassa mutually decompose each other.—*R. Phillips Quart. Jour.* i. 80.   *Dulong. in Phil. Magazine*, 41.

REFERENCES.   *The article* ' Chemical Decomposition,' *in the Supplement to the Encyclopedia Britannica, by Dr. Thomson.   Turner's Chemistry, section on Affinity. Murray's Chemistry, Book* 1, *on Attraction. Davy's Elements of Chemical Philosophy.   Ure's Chemical Dictionary, Art. Attraction.   Brande's History of Chemistry.   Henry's Chemistry,* 11th ed. 1. *Bishop Watson on the various phenomena attending the solution of salts, in Phil. Trans.* 1770, 235, *and in the Chemical Essays,* v. 43.   *Gay Lussac on the solubility of the salts in water.   Ann. of Phil.* xv. 1.

SECTION III.

OF THE PROPORTIONS IN WHICH BODIES COMBINE ; AND OF THE ATOMIC THEORY.

In the chemical combination of bodies with each other, the following circumstances deserve to be mentioned.

I. *Some bodies unite in all proportions ;* for example, water and sulphuric acid, and water and alcohol.

II. *Other bodies combine in all proportions, as far as a certain point, beyond which, combination no longer takes place.* Thus water will take up successive portions of common salt, until at length it becomes incapable of dissolving any more. In cases of this sort, as well as in those included under the first head, combination is weak and easily destroyed, and the qualities, which belonged to the components in their separate state, continue to be apparent in the compound.

It is necessary however, to remark, that these two deductions, though they appear to be warranted by a general survey of the phenomena, are not absolutely and strictly true ; for though some acids, for instance, appear to unite with water in every proportion, yet there are certain relative qualities of water and acid which form the most energetic compounds, distinguished by their permanency and peculiar properties.—*Henry's Chem.* i. 43.

III. *Some bodies unite in one proportion, or in a few proportions only.* Chlorine and hydrogen combine in no other proportions than those constituting muriatic acid. On the other hand, carbon and oxygen unite in two proportions ; oxygen and nitrogen in five proportions, &c. The greatest number of compounds that any two substances are known to produce, is six, if we except those noticed in the preceding paragraphs.

The combination of bodies that unite in this manner, is regulated by the following laws :

I. *The composition of bodies is fixed and invariable.* A compound substance so long as it retains its characteristic properties, must always consist of the same elements united together in the same proportion. Muriatic acid, for example, is always composed of 35.45* parts by weight of chlorine, and one of hydrogen ; no other elements can form it, nor can its own elements form it in any other proportion. Water, in like manner, is formed of 1 part of hydrogen and 8 of oxygen ; and were these two elements to unite in any other proportion, some new compound, different from water, would be the product. The same observation applies to all other substances, however complicated, and at whatever period they were produced. Thus, sulphate of baryta, whether formed ages ago by the hand of nature, or quite recently by the operations of the chemist, is always composed of 40 parts of sulphuric acid and 76.7 of baryta. This law, in fact, is universal and permanent. Its importance is equally manifest. It is the essential

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* I adopt, with few exceptions, the equivalent numbers of Dr. Turner.

basis of chemistry, without which the science itself could have no existence.— *Turner's Chem.*

II. *The relative quantities in which bodies unite, may be expressed by proportional numbers.* Thus 8 parts of oxygen unite with one part of hydrogen, 16 of sulphur, 35.45 of chlorine, 40 of selenium, and 108 parts of silver. Such are the quantities of these five bodies which are disposed to unite with 8 parts of oxygen ; and it is found that when they combine with one another, they unite either in the proportion expressed by those numbers, or in multiplies of them according to the third law of combination. Thus sulphuretted hydrogen is composed of 1 part of hydrogen and 16 of sulphur, and bisulphuretted hydrogen, of one part of hydrogen, to 32 of sulphur ; 35.45 of chlorine unite with one of hydrogen, 16 of sulphur, and 108 of silver, and 40 parts of selenium with 1 of hydrogen, and 16 of sulphur.

From these examples it is manifest, that bodies unite according to proportional numbers ; and hence has arisen the use of certain terms, such as *proportions, combining proportions, proportionals,* or *equivalents* to express them. Thus the combining proportions of the substances just alluded to are—

Hydrogen	1
Oxygen	8
Sulphur	16
Chlorine	.35.45
Selenium	40
Silver.	108

This law also applies to compound bodies. Thus water is composed of one proportional or 8 parts of oxygen, and one proportional or 1 part of hydrogen, and hence its combining proportion is 9. The proportional of sulphuric acid is 40, because it is a compound of one proportion or 16 parts of sulphur, and three proportions or 24 parts of oxygen. And this law applies not only to compounds of two elementary bodies, but to the salts ; the latter of which indeed, furnish the most striking illustrations of this subject.

III. *When one body A unites with another body B in two or more proportions, the quantities of the latter, united to the same quantity of the former, bear to each other a very simple ratio.* These ratios of B may in all cases be represented by one or other of the two following series :—

1st.—A unites with 1, 2, 3, 4, 5, &c. of B.

2d.—A unites with 1, 1 1-2, 2, 2 1-2, &c. of B.

The following table exemplifies the first series.—

Water is composed of	Hydrogen	1	Oxygen 8	1
Deutoxide of hydrogen	Do.	1	Do. 16	2
Carbonic oxide	Carbon	6	Do. 8	1
Carbonic acid	Do.	6	Do. 16	2
Nitrous oxide	Nitrogen	14	Do. 8	1
Nitric oxide	Do.	14	Do. 16	2
Hyponitrous acid	Do.	14	Do. 24	3
Nitrous acid	Do.	14	Do. 32	4
Nitric acid	Do.	14	Do. 40	5

It will be observed that in all the above cases the ratios of the oxygen
3*

are expressed by whole numbers. In water the hydrogen is combined
with half as much oxygen as in the deutoxide of hydrogen, and hence
the ratio is as one to two. The same may be said of carbonic oxide
and carbonic acid. In the compounds of nitrogen and oxygen the latter
is in the ratio of 1, 2, 3, 4, & 5. This ratio also extends to the combi-
nations of combustibles with each other and to the salts. It may be il-
lustrated by a very simple experiment, first made by Dr. Wollaston;
let a given weight of *bicarbonate* of potassa be thrown into a tube
over mercury, and diluted sulphuric acid sufficient to cover it, be in-
troduced into the tube, when a certain volume of carbonic acid gas
will be disengaged; let an equal weight of the *carbonate* of potassa be
treated in the same way and it will be found to give off exactly half as
much carbonic acid gas.

The second series is exemplified in the following compounds:

Protoxide of iron consists of		Iron	28	Oxygen	8 } 1	
Peroxide	. . .	Do.	28	Do.	12 } 1½	
Protoxide of lead .	. .	Lead	103.5	Do.	8 } 1	
Deutoxide	. . .	Do.	103.5	Do.	12 } 1½	
Peroxide	. . .	Do.	103.5	Do.	16 } 2	
Arsenious acid	. .	Arsenic	37.7	Do.	12 } 1½	
Arsenic acid	. .	Do.	37 7	Do.	20 } 2½	
Hypo-phosphorous acid	.	Phosphorus	15.7	Do.	4 } ½	
Phosphorous acid	.	Do.	15.7	Do.	12 } 1¼	
Phosphoric acid	.	Do.	15.7	Do.	20 } 2¼	

Both of these series, which together constitute the third law of com-
bination, as Dr. Turner remarks, result naturally from the operation
of the second law. The first series arises from one proportion of a
body uniting with 1, 2, 3 or more proportions of another body. The
second series is a consequence of two proportions of one substance
combining with 3, 5, or more proportions of another. Thus if two
proportions of phosphorus unite both with 3 and 5 proportions of oxy-
gen, we obtain the ratio of 1 1-2 and 2 1-2; and should one proportion of
iron combine with one of oxygen, and another compound be formed of
two proportions of iron to three of oxygen, then the oxygen united with
the same weight of iron would have the ratio, as in the table, of 1 to
1 1-2. And the compounds of lead and phosphorus with oxygen, af-
ford examples of the same kind. *Turner's Chem.* 4th ed.

IV. *Gases or airs unite in the most simple ratios of volume or bulk.*
This important fact was discovered by Gay Lussac. Thus 1 volume
unites to 1, or 1 to 2, or 1 to 3, &c. In combination by weight there is
no simple multiple ratio between the weight of the elements in the first
compound; the oxygen for example, is not equal to, or twice or thrice,
&c. the weight of the nitrogen in nitrous oxide, or of carbon in carbon-
ic oxide; it is only when there is a second compound formed of the
same elements, that the new proportions of the body which has been
added, become a multiple of the first. But in combinations by volume,
the bulk of one of the gases in the first, as well as in the other com-
pounds, is always equal to, or is some multiple of that of the other: thus,

100 of oxygen combine with 200 hydrogen.
100 ammonia   "   "   50 carbonic acid.
100 ammonia   "   "   100 carbonic acid.
100 nitrogen   "   "   50, 100, 150, 200.
                              and 250 volumes of oxygen.

Another curious fact established by Gay Lussac is that the diminu-
tion of bulk, which gases frequently suffer in combining is also in a
very simple ratio. Thus the four volumes of which ammonia is con-
stituted, (3 volumes of hydrogen and 1 of nitrogen,) contract to one
half or two volumes when they unite. There is a contraction to two-
thirds in the formation of nitrous oxide, to one half in the formation of
sulphuretted hydrogen, and to one half in that of sulphurous acid
&c. [For a more full exposition of this law see *Henry's Chem.*
i. 55.]

V. *The respective quantities of any number of alkaline, earthy or me-
tallic bases required to saturate a given quantity of any acid, are always
in the same ratio to each other, to whatsoever acid they be applied.*

This law appears to have been discovered by Richter of Berlin, in
1792, and has been fully confirmed by succeeding chemists.

For an illustration of it let us take potassa and soda for the bases,
and sulphuric acid for the acid. Having found by experiment that
two parts of soda will saturate as much of the acid as three of the pot-
ash, their power of saturating every other acid is in the ratio of two to
three. Thus if we should ascertain by experiment that it required 4
parts of soda, to neutralize any given quantity of nitric acid, we should
know without experiment that it would require 6 parts of potash to
neutralize the same amount of nitric acid. Two parts of soda are
therefore said to be equivalent to three of potash. This rule applies as
well to all the acids as to the bases, and greatly facilitates chemical in-
vestigations. Thus if we have 100 bases and 50 acids, we have only to
apply each of these bases to any one of the acids, and one of the bases
to all the acids, to ascertain the amount of all the other bases necessary
to saturate all the acids. Hence we need only perform 149 experiments
instead of 5000 which we should be obliged to do without a knowledge
of this law.

By arranging the numbers indicating the relative combining weights
or equivalent quantities of different substances on a moveable scale,
and writing against them the names of the substances they respectively
represent, Dr. Wollaston constructed a *Scale of chemical equivalents,*
an instrument stamped with the accuracy and ingenuity of its author,
and of great value to the practical chemist.—*Phil. Trans.* 1814.

In this instrument the slide is a line of numbers on which equal dis-
tances denote equal ratios. The distance between 50 and 100, for
example, is the same as that between 1 and 2, because 50 : 100 : : 1 : 2.
Opposite to the numbers on this scale, are written the names of the
bodies of which the numbers themselves are the equivalents; then the
distances between these bodies are in like manner the measures of the
ratios of their combining quantities, and will be the same with the dis-
tances between the numbers. But the chief value of the arrangement
is, that by means of the slide, we can at once solve a great number of
cases which arise out of combinations and decompositions, the solution
of which in the ordinary way would require a tedious number of com-
putations.

As the proportional numbers merely express the relative quantities
of different bodies which unite together, it is of no consequence what
figures are employed to express them, provided the relation is strictly
observed : Thus Dr. Thomson makes oxygen 1, so that hydrogen is 8
times less than unity, or 0.125, carbon 0.75, and sulphur 2. Dr. Wol-
laston in his scale of equivalents, fixes oxygen at 10, by which hydro-

gen is 1.25, carbon 7.5, &c. But the greatest number of chemists call hydrogen unity and therefore oxygen 8. This is much the most simple, and has been adopted in the scale of equivalents constructed by Professor Henry and myself, and also in the present work. A very complete scale of chemical equivalents has been drawn up by Mr. Prideaux of Plymouth, Eng.— *Phil. Mag. & Annals.* viii. 430.

The utility of being acquainted with the important laws which have here been given is almost too manifest to require notice. Through their means our knowledge of the composition of bodies is much simplified. The exact quantities of bodies necessary to produce a desired effect can also be at once determined with certainty, and these laws thus become highly useful both in the practice of the chemical arts and in the operations of pharmacy. The same knowledge, moreover, affords the best guide to the analyst, by which to judge of the accuracy of his results. Thus a powerful argument in favour of the accuracy of an analysis is derived from the correspondence of its results with the laws of chemical combination. On the contrary, if it forms an exception, it may be considered doubtful, and we may hence be led to detect an error, which might otherwise have escaped notice.

It may be observed that these laws are deduced from experiment, and the student should be careful to keep them distinct from the theory which has been proposed to account for them. Whatever may be the fate of this theory, it cannot affect these laws, though the progress of discovery may render it necessary that they should be modified.

ATOMIC THEORY.

The foregoing are the principal *facts*, which the experimental examinations of chemical combinations and decompositions have unfolded. To account for these facts a theory has been invented which is denominated the *Atomic Theory ;* and which derives much probability from the complete solution it affords of the laws of attraction. For the full developement of this theory we are indebted to the labours of Mr. Higgins and Mr. Dalton.

The atomic theory proceeds on the supposition that every body is an assemblage of minute, solid particles, without considering whether a farther division of them be possible or not. The question of the infinite divisibility of matter is not therefore involved ; the theory only assumes that matter is not, in fact infinitely divided. These undivided particles are the *atoms* in question. It is also assumed that these atoms differ from each other in weight, whether this difference is owing to specific gravity or size, or both together, is not material.— *Thomson's First Prin.*

It is further supposed that though we appear, when we affect a chemical union, to operate on *masses*, the combination only takes place between these ultimate particles or atoms.*

To apply this theory, let us take the compounds of nitrogen and oxy-

* An ingenious method of illustrating this theory has been invented by Professor Hadley of the college of Physicians and Surgeons of the Western District. It consists of a box containing a number of cubical blocks, which are variously coloured to represent the principal elementary substances. By these representatives of atoms, the laws of combination may be strikingly presented to the student, and many of the more complex chemical decompositions rendered apparent.

gen, which are five, differing much from each other: viz.: nitrous ox-
ide, nitric oxide, hyponitrous acid, nitrous acid and nitric acid. If we
take a given quantity of nitrogen, say 14 grains, and combine it with
8 grains of oxygen, we form nitrous oxide ; with 8 more, we have ni-
tric oxide; with 8 more, hyponitrous acid; with 8 more, nitrous acid;
with 8 more, nitric acid. Now supposing that these several compounds
are formed by the union of a certain number of atoms of oxygen, the
latter number varying in the several compounds, the first compound is
probably formed of an equal number of atoms of each element. It is
plain that one atom of nitrogen can combine with no less than one
atom of oxygen, because the atoms are, by the hypothesis, indivisible,
or at least undivided. Nor is it probable, that, in forming the first
compound, one atom of nitrogen combines with any more than one
of oxygen ; for this union is the most simple and hence the most natu-
ral. The first compound then being formed of one atom of nitro-
gen and one of oxygen, it is plain that no new compound can be form-
ed, until we add at least one atom of oxygen ; and hence the reason
is evident why in all the higher combinations the quantity of oxygen
is just twice, or thrice, or four times that in the lowest, there being
respectively just twice, or thrice, or four times as many atoms of oxy-
gen.

In cases where two bodies unite only in one proportion, it is assumed
that they unite atom to atom ; and hence if we determine the relative
weights of the masses, which enter into combination, we can easily
determine the relative weights of the atoms ; the ratio being the same.
Thus chlorine and hydrogen combine only in one proportion, forming
muriatic acid. The volume of each is the same, but the weight of the
volume of chlorine is 35.45 times greater than that of the volume of
hydrogen ; hence the atom of chlorine is to that of hydrogen as 35.45
to 1.

The weight of the atoms of all other bodies is ascertained in the
same manner. Thus an atom of carbon is six times, and an atom of
sulphur 16 times heavier than that of hydrogen ; and this is precisely
the reason why they unite with each other in the proportions express-
ed by those numbers. What are called proportional or equivalent
numbers, are therefore, in fact nothing else but the relative weights of
atoms.[*]

The two assumptions, which indeed constitute the basis of this theo-
ry, would be considered gratuitous, were it not for the complete expla-
nation which they afford of the laws of definite proportions.—They
are further supported by the fact, that the weight of an atom comes
out the same when deduced from different premises. This theory is
also confirmed by the observations of Dr. Wollaston, in his essay
on the finite extent of the atmosphere.—[*Phil. Trans.* 1822.] And
another argument which appears to amount almost to demonstration,

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[*] These terms have been proposed to avoid theoretical annunciations ; but
the term *atom* originally proposed by Mr. Dalton is generally employed in this
work as being the most convenient. And I think Dr. Thomson has correctly re-
marked that " unless we adopt the hypothesis with which Dalton set out, name-
ly that the ultimate particles of bodies are *atoms* incapable of farther division, and
that chemical combination consists in the union of these atoms with each other,
we lose all the new light which the atomic theory throws upon chemistry, and
bring our notions back to the obscurity of the days of Bergman and Berthollet,"
—*History of Chemistry.*

is deducible from the peculiar connexion noticed by Professor Mits-cherlich, between the form and composition of certain substances. —*Ann. de Chim. et de Phys.* xiv. 172, xix. 350. and xxiv. 264 and 365.

There is a seeming objection to the atomic theory in those cases where one proportion of one body combines with one proportion and a half of another. In such cases, however, it is supposed that two atoms of the one are combined with three atoms of the other, by which the exact ratio is preserved, and the idea of a fraction of an atom avoided.

If the atoms occupied the same space when in a gaseous form, they might be represented by volumes, and their proportional numbers would be identical with their specific gravities. This, however, is not the case. The atom of hydrogen, and several other gaseous substances occupy twice the space of an atom of oxygen: but in such cases it is easy to calculate the specific gravity by multiplying the atomic weight by half the specific gravity of oxygen.

It might at first view appear that the atoms and volumes could be made to correspond, if we considered water as a compound of two atoms of hydrogen and one atom of oxygen. This has been proposed by Sir H. Davy, and advocated by other chemists: but it increases instead of removing the difficulty. Thus sulphuretted hydrogen, on this supposition, must be considered as consisting of one atom of sulphur and two atoms of hydrogen, while it is composed of one volume of each of the constituents. Muriatic acid gas would be formed of one atom of chlorine and two atoms of hydrogen, though constituted in like manner of one volume of each gas. And the same remark would be applicable to hydriodic acid, hydrocyanic acid, and indeed to most other compound gases containing hydrogen. For this and other reasons which might be given, water is considered a compound of one atom of hydrogen and one atom of oxygen, though the volume of oxygen is only one half that of the hydrogen.

The learner will now see the reason why the atomic weight of oxygen is fixed at 8 compared to hydrogen 1, although its specific gravity is 16 when compared to the same substances as unity.

REFERENCES.—*Turner's Chemistry. Ure's Chem. Dictionary, Art. Equivalent. Professor Olmstead on the present state of Chemical Science. Silliman's Jour.* xii. 1 *; a paper containing a lucid explanation of the Laws of Combination and of the Atomic Theory, from which some of the ideas in the above section are obtained. McNevin on the Atomic Theory. Thomson's First Principles. Dalton's new system of Chemical Philosophy,* v. 1. *Berthollet's Chemical Statics. Some interesting papers concerning the Atomic Theory, by Berzelius, Dalton and Thomson, will be found in the 2d, 3d, 4th and 5th volumes of the Annals of Philosophy. Berzelius Traité de chimie. Davy's Elements of Chemical Philosophy. Daubeny on the Atomic Theory. Prout's Bridgewater Treatise.*

CHAPTER II.

HEAT OR CALORIC.

The term Heat, in common language, has two meanings ; in the one case it implies the sensation experienced on touching a hot body ; in the other it expresses the cause of that sensation.   To avoid any ambiguity that may arise from the use of the same expression in two such different senses, the word *caloric* (from the latin *calor*, heat) has been adopted to designate exclusively the principle or cause of the feeling of heat ; but to prevent repetition, the terms *caloric* and *heat* are both occasionally employed to designate the cause in question.

This subject will be treated of in the following order :

1. THE NATURE OF CALORIC.
2. ITS COMMUNICATION.
3. ITS DISTRIBUTION.
4. ITS EFFECTS.
5. SPECIFIC CALORIC.
6. THE SOURCES OF CALORIC.

SECTION I.

NATURE OF CALORIC.

Upon this point philosophers are divided into two sets ; the one maintaining that caloric is a mere property of matter ; the other that it is a distinct substance. The former was an old opinion, but was adopted by Sir H. Davy, and is at the present time quite generally received in France.   The latter was maintained by Sir Isaac Newton ; and as this affords a more easy explanation of most of the chemical phenomena, it will be adopted in the present treatise.

Caloric, on the supposition of its being material, is a subtle fluid, the particles of which repel one another, and are attracted by all other substances. It is imponderable ; that is, it is so exceedingly light that a body undergoes no appreciable change of weight, either by the addition or subtraction of caloric. It is present in all bodies, and cannot be wholly separated from them. For if we take any substance whatever, at any temperature, however low, and transfer it into an atmosphere, whose temperature is still lower, a thermometer will indicate that caloric is escaping from it.   That its particles repel one another, is proved by observing that it flies off from a heated body ; and that it is attracted by other substances, is equally manifest from the tendency it has to penetrate their particles and be retained by them.— *Turner.*

Caloric has also been defined as the agent to which the phenomena of heat and combustion are to be ascribed. So far as chemical agencies are concerned it is, 1st. An antagonist power to cohesive attraction ; and, 2d. It concurs with, and increases elasticity.

Caloric in many of its properties, resembles light. As for example, in those of refraction, reflection and radiation, and in the repulsion

which exist between its particles. This latter property, indeed, is so striking that caloric is often treated of under the appellation of *calorific repulsion.*

As the presence of caloric produces the sensation of heat, so its absence produces that of cold. This last sensation, therefore, is not to be considered as produced by any particular agent, but as altogether a negative expression.

Caloric exists in two states, viz.: *free or sensible,* and, *latent or combined.*

In the former state it is capable of exciting the sensation of heat and producing expansion in other bodies, and to it the term *caloric of temperature* has also been applied. By the term *temperature,* we are to understand the state of a body relatively to its power of exciting the sensation of heat, and occasioning expansion; effects, which in all probability, bear a proportion to the quantity of free caloric in a given space, or in a given quantity of matter. Thus what we call a high temperature may be ascribed to the presence of a large quantity of free caloric; and a low temperature to that of a small quantity. We are unacquainted, however, with the extremes of temperature; and may compare them to a chain, of which a few of the middle links only are exposed to our observation, while its extremities are far removed from our view.—*Henry's Chem.* i. 82.

In the latter state, caloric exists either in combination with bodies or in something resembling it. Under these circumstances, it does not possess its distinguishing properties—cannot be discovered by our senses or by the thermometer, and produces important and sometimes permanent changes in the bodies with which it combines. The difference between these two states may be shown by the following experiment.

Exp. Place two vessels of thin glass, the one containing water and the other a small portion of sulphuric acid, in contact with the bulb of an air thermometer. Allow them to remain in this situation for a short time, to show that the thermometer is not affected by them. Now empty the sulphuric acid into the water, when it will be seen that the liquid in the thermometer descends, owing to the expansion of the air by the caloric which has been rendered free by the mixture. The common fire syringe offers another striking illustration of the difference between combined and free caloric.

REFERENCES.—*For a notice of facts and reasonings concerning the nature of Caloric, see Thomson's Chemistry,* vol. 1 ; *and Library of Useful Knowledge, Art. Heat. Professor Hare's paper, on the materiality of Heat, and the discussion on this subject between him and Prof. Olmstead. Silliman's Amer. Jour.* vols. iv. xi. xii. xiii.

SECTION II.

COMMUNICATION OF CALORIC.

Caloric is radiated in all directions, and moves with great velocity. It is also absorbed by certain bodies, and when it has thus entered, it makes its way through the body. In the latter case its motion is comparatively slow. Hence caloric is communicated,

1. BY RADIATION.
2. BY CONDUCTION.

RADIATION.

When the hand is placed above a heated ball, or a fire, the sensation of heat is perceived; and the same thing also takes place when the hand is placed below the source of caloric. Now as nothing intervenes in the last case but the air, and as this fluid, when caloric is communicated to it, expands and rises, the impression cannot be owing to the transmission of hot air to the hand; but rather to the action of the particles of caloric which are supposed to be thrown off in all directions. Bodies capable of discharging caloric in this way are called *radiating*; and the principle which is thus projected is denominated *Radiant Caloric*.

Radiant Caloric is reflected.

This fact can be shown in a familiar manner, by standing at the side of a fire in such a position that the caloric cannot reach the face directly, and then placing a plate of tinned iron opposite the grate and at such an inclination as permits the observer to see in it the reflection of the fire; as soon as it is brought to this inclination, a distinct impression of heat will be perceived upon the face. If a line be drawn from the heated substance to the point of a plane surface from which it is reflected, and a second line from that point to the spot where it produces its effect, the angles which these lines form with a line perpendicular to the reflecting plane are equal to each other, or in philosophical language, the angle of incidence is equal to the angle of reflection.— *Turner.*

This may be illustrated in a still more striking manner, by the experiment devised by Pictet, which is, to take two concave mirrors of planished tin or copper, and to place them at a distance of from 9 to 12 feet apart, with their concave surfaces towards each other. If now a hot ball or a small basket of coals is placed in the focus of one mirror, it will instantly affect a thermometer in the focus of the other; or if a piece of phosphorus be substituted for the thermometer, it will soon be kindled.

Now these phenomena cannot be explained upon the supposition that the heat of the ball or of the coals is communicated directly to the thermometer through the medium of the air which intervenes; for upon this hypothesis, a point intermediate between the two mirrors would be of a higher temperature than that directly in the focus, which is not the case. There must, therefore, be something emanating from the ball or the coals which is reflected by the mirrors, and is concentrated also into a focus, so as to affect the thermometer and the phosphorus.

When the heated ball is placed near the mirror, rays of heat fly off from it in straight lines in all directions; some of these strike the mirror, by which they are instantly reflected again in straight lines to the opposite one, where they are also reflected, and are thus brought to a point where the heating effect is produced. The distance at which this takes place, depends of course on the form of the mirror; and the effect is much greater when burning charcoal is employed instead of the heated ball. But the thermometer is affected even when a glass of boiling water is substituted for the heated ball.

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Radiant Caloric is absorbed.

This may be shown by placing a thermometer before the fire or any heated body, when the mercury will be seen to rise in the stem. And it has been ascertained that the intensity of effect diminishes according to the squares of the distance from the radiating point. Thus the thermometer will indicate four times less heat at two inches, nine times less at three inches, and sixteen times at four inches, than it did when it was only one inch from the heated substance.

It is therefore evident that a hot body placed in the air is the centre of a multitude of calorific rays ; that these rays traverse the air almost without resistance ; and that when they fall upon the surface of a solid or liquid substance they are either reflected from it and receive a new direction, or lose their radiant form altogether, and are absorbed. With regard to caloric then, three powers may be recognized as belonging to bodies, viz. 1. The power of emitting or radiating caloric ; 2. The power of absorbing ; and 3. The power of reflecting caloric. These powers appear to depend chiefly upon the temperature, and polish upon the surface of the body ; their nature having but little influence.

Temperature. The higher a body is heated, the greater is its radiating power ; for then the caloric of the body has greater tension, or in other words, makes more effect to escape.

Polish of surface. When even a large quantity of radiant caloric falls upon a metallic body highly polished, the body is scarcely heated ; from which we infer that all the caloric has been reflected. But if we blacken the surface of this body and expose it again to the same amount of caloric, it becomes considerably heated ; and in this case nearly all the caloric will be absorbed.

Polish influences the radiating, as well as the absorbing and reflecting power. This is strikingly illustrated by the experiment of Mr. Leslie. He coated one side of a canister with lampblack, covered a second with writing paper, applied to a third a pane of glass, and left the fourth bright and polished. The canister was now filled with boiling water and placed in the focus of the mirror. When the metallic surface was presented to the reflector, the impression upon the thermometer amounted to 12° ; from the glass surface it was equal to 90° ; from the papered side 98° ; and 100° from the lampblack.

Colour of surface. The influence of colour over the radiating and absorbing powers of bodies, so far as solar heat, or terrestrial heat accompanied with light is concerned, has long been observed. Dr. Stark of Edinburgh has, however, recently shown that this extends also to simple heat. The bulb of a delicate thermometer was successively surrounded by equal weights of differently coloured wool, was placed in a glass tube heated by immersion in hot water to 180° and then cooled to 50° in cold water. The times of cooling were 21 minutes with black wool, 26 with red wool, and 27 with white wool. Similar results were obtained with flour of different colours. On the other hand, when different coloured wools, were wound upon the bulb of a thermometer and exposed within a glass tube to hot water they rose from 50° to 170° in the following times,—black wool in 4′ 30″, dark green in 5′, scarlet in 5′ 30″, white in 8′.—*Phil. Trans. for* 1833. *Part.* ii.

Ratios of the radiating, absorbing and reflecting powers. The powers of bodies to radiate and absorb caloric are directly proportional to each

other. Those which absorb with the most ease also radiate with the greatest facility. If in the usual arrangement, the bulb of the thermometer be coated with tin foil, or even gold leaf, the impression of the radiant caloric will be exceedingly slight ; if the bulb be naked, the effect will be much greater, but if it be coated with lampblack, the action on the instrument will reach its maximum. Now experiments have proved that lampblack absorbs more than glass, and glass more than the metals, which is exactly the order of their radiating powers. —*Leslie's Inquiry.*

The powers of radiation and reflection are inversely proportional to each other. Those bodies which reflect the most, radiate the least, and those which radiate the most, reflect the least caloric. Thus metals reflect heat with great facility ; but if a glass mirror be substituted for the metallic reflector, the positions of the hot body and the thermometer being the same, the effect will be considerably diminished, and if the surface of the glass be coated with lampblack, no action upon the thermometer will be perceived.

The vast superiority of metallic bodies over glass in reflecting caloric may be proved by a very simple experiment. In the focus of the commonest tin reflector, if at all approaching to a concave or parabolic form, when held before a large fire, a considerable degree of warmth will be perceived ; whereas the best glass mirror of the same dimensions will hardly collect in its focus heat enough to be felt.

On the other hand, glass radiates more caloric than the metals, and lampblack more than glass. If the surface of the metallic mirror be furrowed or roughened, or if it be covered with a thick film of amalgam, its power to reflect caloric will be diminished, while the power to radiate will be proportionably increased. Metallic bodies possess this property in different degrees, and it will be seen, by inspecting the table of Mr. Leslie, that those which reflect the most, radiate the least, and that the converse of the proposition is equally true. It also appears, as might be expected, that the reflecting and absorbing powers of bodies are in the inverse ratio to each other.

Rate of radiation through different bodies. In ordinary cases heat is radiated through the medium of the air ; and no sensible radiation takes place when the whole apparatus is plunged into water—although the experiments on this point are not free from objection. It radiates through all gaseous bodies tried, and it does not appear that the rate of radiation is much influenced by the surrounding medium. The rate is the same at least, in air, and in hydrogen gas ; and oxygen and nitrogen appear to have the same properties in this respect as air. Mr. Leslie has shown also that the rarification of the surrounding air diminishes somewhat the radiating energy of surfaces ; but the radiation diminishes at different rates in different gases. He has given a table showing the diminution of the power of radiation in air and in hydrogen gas of different degrees of rarity ; but perhaps the experiments require to be repeated.

It has been supposed that solid bodies are impermeable to radiant caloric, and an experiment is described in some chemical works as a conclusive proof of the difference between caloric and light. It consists in placing a lamp or burning coals in the focus of a mirror, and a pane of glass between it and the opposite mirror : the rays of light will pass through the glass, but the rays of caloric, it is said, will be completely intercepted. But this distinction can scarcely be maintained. It is true indeed that the thermometer is not so much

affected as it would be were no screen interposed, and the glass itself becomes warm. These facts prove that the greater part of the calorific rays are intercepted by the glass. But the thermometer is affected to a certain degree, and the question is, by what means do the rays reach it? Professor Leslie contends, that all the rays which fall upon the glass are absorbed by it, pass through its substance by its conducting power, and are then radiated from the other side of the glass towards the thermometer—an opinion, which Dr. Brewster has ably supported with an argument, suggested by his optical researches.— [*Phil. Trans. for* 1816, p. 106.] The experiments of Delaroche, on the contrary, [*Biot. Traité de Physique*] lead to the conclusion that glass does transmit some calorific rays, the number of which, in relation to the quantity absorbed, is greater as the intensity of the heat increases. This general result has been confirmed by various other philosophers.

Mr. Leslie has advanced the idea that radiant caloric is not thrown off from hot bodies and darted through the air to distant bodies, but that the air itself is the medium of its transmission. According to this hypothesis, the stratum of air immediately in contact with the heated body acquires a portion of its high temperature, by which it is expanded and made to press upon the next stratum of particles; this in like manner recedes, and thus an undulation or chain of aërial pulsations is produced. " The mass of air, without sensibly changing its place, suffers only a slight fluctuation as it successively feels the partial swell; but the heat attached to this state of dilatation is actually transported, and with the swiftness of sound."—*Leslie's Inquiry*, p. 140.

But the experiments of Delaroche and others, offer insuperable objections to the adoption of Leslie's theory, and indeed go to prove that there is but little difference between the radiation of heat and light.

Apparent radiation of Cold. When a cold body, as ice or a vessel containing a mixture of snow and salt, is placed in the focus of one of the mirrors, instead of the hot body, the bulb of the thermometer in the focus of the other mirror will indicate a diminution of temperature below that of the surrounding air. This fact led some philosophers to advance the opinion that cold was a material substance, and subject, like heat, to the laws of radiation and reflection. But this, as well as the other phenomena of radiant caloric, will be explained in the section on the distribution of temperature. It should be observed, that in all these experiments upon the radiation of caloric, the *Differential Thermometer*, described in Section 4, should be employed.

REFERENCES. *Leslie's Inquiry. Pictet's Essay. Delaroche on Radiant Heat, Ann. of Phil.* ii. 100. *Ritchie, in Edin. Phil. Jour.* xi. 281. *Prof. Powell in Repertory of Inventions,* iv. 394.—*Also Ann. of Phil.* xxiv, xxv, and xxvi. *Powell's Report on Radiant Heat to the British Association,* 1832.

CONDUCTION.

Another method in which heat is communicated, is by what has been aptly termed *conduction,* which differs considerably from radiation. The most striking point of difference, however, is the velocity with which caloric is transmitted. When caloric is radiated, its mo-

tion is rapid, nay almost instantaneous;—when it is conducted, its motion is slow. These two modes of communication, however, are seldom perfectly independent of each other. When caloric is radiated through the air, a portion is also conducted by the air which comes in contact with the rays. And again, when caloric is conducted through a solid body, for example, radiation at the same time takes place. The difference in the velocity of transmission will explain why, in the former case, only a small portion of heat is conducted, and in the latter case why so large a quantity is radiated.

Caloric is conducted through solids, liquids and æriform substances; in each of these bodies, however, there is some peculiarity in the manner of its conduction.

Conducting powers of Solids.

When a metallic bar, is exposed at one end to the heat of a furnace, the heat is gradually transmitted through its whole length, and after a short time the other extremity cannot be touched without danger of our being burnt. But this may be done with perfect safety with a rod of glass or of wood. Hence bodies are said to differ in their power of conducting caloric, and some are called good and others bad conductors.

Metals are the best conductors of caloric;—but even among these there is considerable difference. According to the experiments of Ingenhouz, silver and gold are the best conductors, next copper and tin, which are nearly equal, and lastly platinum, iron, and lead, which are much inferior to the others.

Glass, pottery, clay, &c. have much less conducting power than any of the metals. This is the reason why glass is so liable to break when suddenly heated or cooled; one part of it is receiving or parting with its caloric before the rest expands or contracts, and hence the cohesion is destroyed. It is on this account that the manufacturers resort to a process called *annealing*, which consists in putting the glass while hot, immediately after being formed into the required shape, into an oven strongly heated, where the glass remains till it becomes cold by slow degrees.

Exp. Put a lamp under the centre of a sheet of copper, and at equal distances from the centre place a piece of silver, copper, iron and porcelain, of the same size and thickness, having on each a small bit of phosphorus. That on the silver will be first kindled, showing that it is soonest heated; in other words, that the caloric has passed most quickly through it. Next comes the copper, then the iron, and lastly the porcelain, the phosphorus on which will remain a long time, without being kindled.

Next to these bodies in point of conducting power, come the dried woods, which also differ materially from each other. According to Professor Mayer, the conducting power of these is inversely as their specific gravities. (*See his table in Webster's Brande.*)

The difference between the conducting power of the metals and wood may be shown as follows:

Exp. Take a smooth cylindrical tube, or still better, a solid piece of metal, about an inch and a half in diameter and eight inches long; wrap a clean piece of writing paper round the metal so as to be in close contact with its surface. When thus prepared it may be held for a considerable time in the flame of a spirit lamp without being in the

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least affected. Wrap a similar piece of paper around a cylindrical piece of wood of the same diameter, and hold it in the flame; it will speedily burn. When the paper is in close contact with the metal, the heat which is applied to it in one particular part can not accumulate there, but enters into the metal, and is equally diffused through its substance, so that the paper cannot be burned or scorched, until the metal becomes very hot : but when the paper is wrapped round wood, the heat that is applied in one particular part, not being able to enter in to the wood with facility, accumulates in a short time in sufficient quantity to burn the paper.—*L. U. K. Art. Heat.*

Charcoal is also a bad conductor : but feathers, silk, wool and hair are worse than any yet mentioned. Count Rumford has made experiments with a view of determining the conducting power of substances of this nature, from which it appears that those have the least conducting power, in which the fibres are finest and most condensed, provided the interstitial air is not expelled by the condensation.—*Rumford's Essays.*

The substances which form the warmest articles of clothing are those which have the longest nap, fur or down, on account of the air which is involved, resisting the escape of the natural warmth of the body. The imperfect conducting power of snow arises from the same cause, and hence its utility in preventing the surface of the earth from being injuriously cooled in many parts of the world. While the temperature of the air in Siberia has been—70° F. it is affirmed that the surface of the earth has seldom been colder than 32° F.

Despretz has given the following table of the comparative conducting powers of the principle metals and some earthy bodies. The results have been confirmed by Prof. Forbes, except as it regards platinum, which he places between iron and tin.—*Traité Elémentaire de Physique.* 1837.

Gold, (greatest conducting power,)						1000.0
Platinum,	-	-	-	-	-	981.0
Silver,	-	-	-	-	-	973.0
Copper,	-	-	-	-	-	898.2
Iron,	-	-	-	-	-	374.3
Zinc,	-	-	-	-	-	363.0
Tin,	-	-	-	-	-	303.9
Lead,	-	-	-	-	-	179.6
Marble,	-	-	-	-	-	23.6
Porcelain,	-	-	-	-	-	12.2
Earth of bricks and furnaces,	-				-	11.4

The conducting powers of bodies have been investigated by Fourier, by the aid of instruments called a *Thermometer of Contact,* and a *Thermoscope of Contact,* from the first of which some curious facts have been ascertained.— See *Henry's Chem.* i. 108. *Ann. de Chem. et de Phys.* xxxvii. 291.

Conducting powers of Liquids.

Liquids may be said, in one sense of the word, to have the power of communicating caloric with great rapidity, and yet they are very imperfect conductors. The transmission of caloric from particle to particle does in reality take place very slowly ; but in consequence of the

mobility of their particles upon each other, there are peculiar internal movements which under certain circumstances may be occasioned in them by increase of temperature; and which do more than compensate for the imperfect conducting power with which they are really endowed.

When certain particles of a liquid are heated, they expand, and thus become specifically lighter than those which have not yet received an increase of temperature; and consequently, according to a well-known law in physics, the colder and denser particles descend, while the warmer ones are pressed upwards. It therefore follows that if caloric enters at the bottom of a vessel containing any liquid, a double set of currents must be immediately established, the one of hot particles rising towards the surface, and the other of colder particles descending to the bottom. Now these currents take place with such rapidity, that if a thermometer be placed at the bottom, and another at the top of a long jar, the fire being applied below, the upper one will begin to rise almost as soon as the lower. Hence, under certain circumstances, caloric is rapidly communicated through liquids.

But if, instead of heating the bottom of the jar, the caloric is made to enter by the upper surface, very different phenomena will be observed. The intestine movements cannot now be formed, because the heated particles have a tendency to remain constantly at the top; the caloric can descend through the fluid only by transmission from particle to particle, a process which takes place so very tardily, as to have induced Count Rumford to deny that water can conduct at all, and to assert that liquids were heated exclusively by their *transporting or carrying power*.—(*Rumford's Essays.*) The incorrectness of this opinion, however, appears to be quite satisfactorily shown by the experiments of Dr. Hope, Dr. Thomson and Dr. Murray; though they all admit that water, and liquids in general, mercury excepted, possess the power of conducting caloric in a very slight degree.*

The transporting power of liquids can be very satisfactorily shown by putting into a vessel of water some small pieces of amber which are in specific gravity so nearly equal to water as to be little influenced by gravitation.

The lowermost part of the vessel being subjected to heat, when thus prepared, the pieces of amber rise vertically, and on reaching the surface, move towards the sides of the vessel, which are colder from the influence of the external air; they then sink and rise again as before.

When the boiling point is nearly attained, the particles being nearly of one temperature, the circulation is retarded. The portions on the surface are converted into steam before they can be succeeded by others; but the steam thus produced cannot rise far, before it is condensed. Hence the vibration and singing observed at this time.— *Hare's Minutes.*

Exp. The slow conducting power of water can be shown by cementing an air thermometer into a glass funnel, and covering the bulb of the instrument with water. If now a small quantity of ether be poured upon the surface of the water, it may be fired without sensibly affecting the fluid in the stem of the thermometer.

* Some ingenious experiments in confirmation of the theory of Count Rumford, by Lieut. W. M. Mather, are detailed in Silliman's Jour. xii. 368.

Conducting powers of Æriform Bodies.

It is extremely difficult to estimate the conducting power of æriform fluids. Their particles move so freely on each other, that the moment a particle is dilated by caloric, it is pressed upwards with great velocity by the descent of colder and heavier particles, so that an ascending and descending current is instantly established. Besides, these bodies allow a passage through them by radiation. Now the quantity of caloric which passes by these two channels is so much greater than that which is conducted from particle to particle, that we possess no means of determining their proportion. It is certain, however, that the conducting power of gaseous fluids is exceedingly imperfect, probably even more so than that of liquids.— *Turner.*

References. *Soquet on the power of Fluids as conductors of Heat, in Repert. of Arts,* 1st ser. xiii. 277. *Dalton on the same subject, in Repert. of Arts,* 2d ser. ii. 282. *Dulong and Petit on the Laws of the communication of Heat, in Ann. of Phil.* xiii. 112. *Murray's Experiments on the conducting power of Liquids, Syst. of Chem.* i.

SECTION III.

DISTRIBUTION OF CALORIC.

Different theories have been proposed to account for the tendency of bodies to acquire an equilibrium of temperature. I shall content myself with an exposition of the theory of Professor Prevost, of Geneva, which though not wholly free from objection, is now generally adopted. It is altogether founded upon the phenomena of radiant caloric.

There appears to be no point of temperature at which radiant caloric is not given out by bodies. Ice, which is so cold when in contact with the hand at ordinary temperatures, becomes hot if it be transported to a chamber whose temperature is 20° below zero, and a mass of melting ice then presented to the thermometer will cause the fluid to ascend as well as the vessel of boiling water presented to it at the ordinary temperature. Again, a mixture of snow and salt cooled down to 20° below zero, becomes a hot body if it be transported to an atmosphere of 40° below zero.

In all these cases, as in our own sensations, there is nothing absolute; all is relative. We are therefore forced to the conclusion that all bodies, at all temperatures, radiate caloric; but that the radiation is of unequal intensity, according to their nature, to their surfaces, and to the temperature to which they are brought. The constancy of the temperature of a body depends then upon an equality in the quantity of radiant caloric which it emits and receives during the same time; and the eqilibrium of caloric which takes place among several bodies by mutual radiation, depends upon the perfect compensation of the instantaneous changes which are effected between all and each of them. This is the ingenious theory suggested by Prevost, and which, combined with the peculiar properties of different surfaces, explains all the phenomena of radiant caloric.

A few experiments will more fully illustrate this interesting subject. Place a thermometer in a chamber which has an equal temperature

in all its parts, and allow it to remain until it becomes of the same temperature. In the same chamber have an opake disk of any nature and form whatever, also at the same time temperature. If now this disk be presented at a greater or less distance to the bulb of the thermometer, no effect will be produced upon it. The reason is obvious. Before we employed the disk, the bulb received at each instant from the walls and from the air of the chamber, a certain quantity of heat by radiation and reflection, and itself at the same time, sent back by this double mode an amount exactly equal, since its temperature remained the same. Now when we present the opaque disk to the bulb of the thermometer, we intercept for each point of the bulb all the calorific rays which are comprised in the cone formed by this point, and the whole surface of the disk. But, in exchange, the same point receives from the disk a certain number of rays comprised in the cone just mentioned ; and in consequence of the supposed equality of tempera- ture, this number is exactly equal to that which came from that por- tion of the wall upon which the disk is projected. Thus after the in- terposition of the disk, each point of the bulb receives still as much heat in the same time, as it received previously ; and as the quantity which it gives out is not changed, it is evident that its temperature and that of the bulb will remain the same.

A different result, however, will be observed, if there be presented to the thermometer a disk whose temperature is either higher or lower than that of the chamber ; for then the number of calorific rays radia- ted or reflected by this disk in a given time will be, in the former case greater, in the latter, less than that which came from the portion of the wall which it conceals.

The same explanation will apply in the cases where two mirrors are employed. Place a thermometer, the bulb of which is blackened, in the focus of one mirror, and allow it to become of the same tempera- ture as the surrounding air, and in the focus of the other mirror, place any body which is of the same temperature. The thermometer will not be affected. The reason will be readily perceived. When the passage of the rays through this last focus was free, there arrived at this point from all parts of space a certain number of calorific rays, which, after they have crossed, fall upon the second mirror, are re- flected from it to the first, and finally are concentrated upon the bulb of the thermometer. These rays are indeed intercepted by the opaque body which we have placed in the focus, but as this is supposed to be of the same temperature with the surrounding space, it transmits by radiation and reflection a number of rays exactly equal, which falling upon the second mirror are reflected to the first, and finally to the ther- mometer ; and hence no change is effected. But this will not be the case when the body placed in the focus is either of a higher or lower temperature than that of the surrounding space and of the thermome- ter. For then the thermometer, after the interposition, will receive through the medium of the mirrors more or less than it received be- fore, and also more or less than it loses in the same time either by re- flection or by radiation. Whence it follows, that the temperature will be elevated in the former case, and reduced in the latter.

These views are fully confirmed by experiment. For as has al- ready been shown, if we place a hot body in the focus of one mirror, the thermometer in the focus of the opposite one will indicate an increase of temperature ; and on the contrary, if we place a piece of ice or a mixture of snow and salt in the focus of one mirror, the thermometer

in the focus of the opposite mirror will indicate a diminution of temperature. All these phenomena can be explained if we only admit that all bodies, however low their temperature, radiate caloric, and in this there is nothing surprising, since our ideas of heat and cold are all relative. Without this admission we should have to adopt the opinion advanced by some philosophers, that cold as well as heat is radiated; an opinion which is not necessary, nor even warranted by the facts.— *Biot. Precis Elémentaire,* ii. 642.

The theory of radiation as thus unfolded, has been succesfully employed by Dr. Wells, in explaining the phenomena of *Dew.* By his numerous and well directed experiments he has amply proved, that the formation of dew is owing to the radiation of caloric from the ground, and he conceives that all the previous explanations fail in not accounting for the production of cold in the dewed body. He has shown that the degree of cold on the surface of grass, &c. is in proportion to the quantity of dew which is formed; that dew appears in the greatest quantity upon those substances which radiate the most caloric ; that the radiation is the greatest, and the dew most copious in calm and serene nights; that the process is diminished or suspended by high winds and by the presence of clouds ; and that in those cases the temperature of the grass, &c. is the same as that of the air.— *Wells' Essay on Dew, &c.*

A similar explanation has been applied by Dr. Wells to various appearances connected with dew, and among these not the least curious is that of the formation of ice during the night in Bengal, when the temperature of the air is above 32° F. This has generally been ascribed to cold produced by evaporation ; an opinion which has been adopted by Davy, Leslie, Thomson and others. Dr. Wells, however, has shown conclusively, that it cannot be owing to this cause ; but that it depends upon the radiation of heat to the heavens. For it is observed that ice is chiefly formed in Bengal during the clearest and calmest nights, when the greatest cold from radiation is observed on the surface of the earth ; and that clouds and winds prevent its formation by preventing, or at least diminishing, the radiation of heat.*

The study of the laws of radiant caloric has lead to important improvements in the construction of fire places ; a subject which engaged the attention of Count Rumford.— *See Rumford's Essays.*

REFERENCES.—*Prevost's Researches sur la Chaleur. Wells' Essay on Dew, &c. Pictet's Essays. Biot's Precis Elémentaire. Sundry papers on Prevost's Theory of Radiant Caloric, by R. Davenport, Prof. Prevost, Dr. Wells and J. Murray, are contained in the Ann. of Phil. v. vi. and* vii.

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* Captain Scoresby found that in the Polar Seas, ice was formed in clear nights when the temperature of the air was several degrees above the freezing point of water ; but that in cloudy nights no ice was formed,—the temperature of the air in both cases being the same. In the last instance there was a constant interchange of caloric between the water and the clouds, by means of which the temperature of the water was preserved nearly equal to the temperature of the air, which was above the freezing point. In the first instance, as there was nothing which could radiate back to the water the caloric which was radiated from it, its temperature sunk below the freezing point, and ice was formed,

SECTION IV.

EFFECTS OF CALORIC.

The general effects of caloric are—

1. EXPANSION.
2. LIQUEFACTION.
3. VAPORIZATION.

EXPANSION.

This is one of the most remarkable effects of caloric. When bodies are heated they become less compact, are increased in bulk, or in other words, expand; and as they cool they return to their former dimensions. Hence caloric is inferred to separate their particles, and is regarded as the *repulsive power*, which is constantly opposed to cohesion. This being the case, it follows that caloric must produce the greatest expansion in those bodies whose cohesive power is the least; and the inference is justified by observation. Thus the force of cohesion is greatest in solids, less in liquids, and least of all in æriform substances; while the expansion of solids is trifling, that of liquids is more considerable, and that of elastic fluids far greater.

Expansion of Solids.

In proof of the expansion of *solids*, we need only take the exact dimensions in length, breadth, and thickness of any substance when cold, and measure it again when strongly heated, when it will be found to have increased in every direction. A familiar demonstration of the fact may be afforded by adapting a ring to an iron rod, the former being just large enough to permit the latter to pass through it while cold. The rod is next heated, and will then no longer pass through the ring. This dilatation from heat and consequent contraction in cooling takes place with a force which appears to be irresistible.

This property of metals has been applied to various useful purposes. The iron band or *tire*, as it is called, of a carriage-wheel, being purposely made a little smaller than the wooden circle, is enlarged by heat so as to embrace the latter, and being then suddenly cooled, by throwing water upon it, is again contracted, and becomes immoveably fixed. An ingenious use of the same principle was made, several years ago, at Paris, by M. Molard, in restoring to the perpendicular, two opposite walls of a building, which had been pressed outward by the incumbent weight. Through strong holes in the walls, opposite to each other, several strong iron bars were introduced, so as to cross the apartment, and to project outside the building sufficiently to allow strong iron plates or *washers* to be screwed upon their ends.—The bars were then heated, and the iron plates screwed up. On cooling, the bars contracted, and drew the separated walls together; and this was repeated till the walls had regained their perpendicular position.

In riveting together the iron plates out of which steam engine boilers are made, it is necessary to produce as close a joint as possible. This is effected by using the rivets red hot; while they are in that state the two plates of iron are rivetted together, and the contraction which the rivet undergoes in cooling draws them together with a force

which is only limited by the tenacity of the metal of which the rivet itself is made.

The degree of expansion, however, is not the same for all solids, and even differs materially in substances of the same class. Thus the metals expand in the following order, the most expansible being placed first,—zinc,* lead, tin, copper, bismuth, iron, steel, antimony, palladium, platinum. The experiments of Petit and Dulong, (*Ann. of Phil.* xiii. 164,) tend to show that unequal degrees of expansion are produced in a bar of metal by a succession of similar increments of heat ; the rate of expansion increasing with the temperature.

The expansion of solids has occupied the attention of many experimenters, whose chief object appears to have been to ascertain the exact quantity that different substances are lengthened, by a given increase of heat, and to determine whether or not their expansion is equable at different temperatures. The Philosophical Transactions of London contain the various dissertations on this subject by Ellicott, Smeaton, Troughton and General Roy : and Biot in his *Traité de Physique*, i. 158, has given the results of experiments performed with great care by Lavosier and La Place. [A table of the linear dilatation of various solids by heat will be found in Ure's Dictionary of Chemistry, and in the Library of Useful Knowledge.]

Expansion of Liquids.

The simplest method of proving the expansion of *liquids* is by putting a common thermometer, made with mercury or alcohol, into warm water, when the dilatation of the liquid will be shown by its ascent in the stem. The experiment is indeed illustrative of two other facts. It proves, first, that the dilatation increases with the temperature ; for if the thermometer is plunged into several portions of water heated to different degrees, the ascent will be greatest in the hottest water, and least in the coolest portions. It demonstrates, secondly, that liquids expand more than solids. The glass bulb of the thermometer is itself expanded by the hot water, and therefore is enabled to contain more mercury than before ; but the mercury being dilated to a much greater extent, not only occupies the additional space in the bulb, but likewise rises in the stem. Its ascent marks the difference between its own dilatation and that of the glass, and is only the apparent, not the actual expansion of the liquid.— *Turner.*

Liquids differ also in their relative expansibilities : ether is more expansible than alcohol, alcohol more than water, and water more than mercury. Those liquids are generally most expansible which boil at the lowest temperature.

Exp. This may be rendered evident by partially filling several glass tubes of equal diameter, furnished with bulbs, with the different liquids and placing them in hot water ; as the liquids expand, they will rise to different heights in the tubes. To render this more apparent, the liquids may be tinged with some colouring matter.

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* This is the order usually given, but according to Dr. Lardner, *lead* is the most expansible of the metals, in the solid state. Its bulk is increased one part in 350 by being plunged into melting ice, and the ice then being raised to the temperature of boiling water ; or in other words, this takes place by a change of temperature, amounting to 180 degrees of the common thermometer.— *Treatise on Heat, in Lardner's Cyclopedia.*

The expansion of various liquids by heat has been studied with great care by Lavoisier and La Place, Petit and Dulong.

Expansion of Æriform Bodies

The expansion of *æriform bodies* by heat may be exemplified by holding near the fire a bladder half filled with air, the neck of which is closely tied, so as to prevent the enclosed air from escaping. The bladder will soon be fully distndeed, and may even be burst by continuing and increasing the heat. All æriform bodies, when deprived of moisture, and even condensible vapours, when not in contact with the liquids from which they have been produced, undergo the same expansion or contraction at all temperatures hitherto tried, by similar additions or subtractions of caloric. This for a single degree of Fahrenheit's thermometer, is $\frac{1}{483}$ part of their bulk, between 32° and 212°, as first determined by Mr. Dalton, and afterwards confirmed by Gay Lussac, and by Petit and Dulong, who have extended the law, up to 572° F. (*Ann. of Phil.* xxix. 117.) This equable expansion of air by equal increments of heat, adapts it for the accurate measurement of temperature. At a cherry red heat, (= about 1035 F.) Sir H. Davy found that a volume of air = 1 at 212° F. became 2.5 volumes.—*On Flame*, 68. *Henry's Chem.* i. 91.

Exceptions to the law of expansion by heat. To the general law of the expansion of bodies by heat, and their contraction by cold, there are, however, some remarkable exceptions. Thus water when cooled down below the temperature of 39° F. expands and continues to do so, until it is converted into ice.* The most remarkable circumstance attending this expansion is the prodigious force with which it is effected. The Florentine academicians burst a hollow brass globe, whose cavity was only an inch in diameter, by freezing the water with which it was filled : and it has been estimated that the expansive power necessary to produce such an effect is equal to a pressure of 27,720 pounds weight. This fact was confirmed by the experiments of Major Williams of Quebec.—*Trans. Royal Society, Edin.* ii. 23.

Salts also, in the act of crystallizing, expand ; and some of the metals, as cast iron, bismuth and antimony, have their dimensions enlarged on congealing. Hence the precision with which cast iron takes the impression of the mould ; and hence also the use of antimony to the type founder. In all these cases, the cause of the expansion is supposed to be the new and peculiar arrangement of its particles. It only occurs in those bodies which upon cooling assume a crystalline or semi-crystalline form,—the particles of which, then occupy more space than when they are liquid. In the case of water, where the expansion commences previous to congelation, it is supposed that the water begins to arrange itself in the order it will assume in the solid state, before actually laying aside the liquid form. If these views are correct, the exceptions to the general law of expansion by heat are rather apparent than real.

One of the important applications of the principle of expansion is

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* The mean of the recent determinations of the true point of the maximum density of water, by Stampfer, Muncke and Crichton is 38.84.—*Johnston's Report on Chemistry.*

to the construction of instruments which, under the designation of *thermometers*, or *thermoscopes*, *pyrometers*, or *pyroscopes*, are now in general use in every part of the civilized world.   Their names are derived from the Greek terms, *thermos*, *pur*, signifying *heat*, *fire*, and *metron*, *skopos*, a *measure*, an *investigator*.

Thermometers.

Air Thermometer.   The invention of the thermometer is generally ascribed to Sanctorio of Padua, who flourished about the beginning of the seventeenth century.   But the instrument employed by that philosopher, was of a very simple kind, and measured variations of temperature by the variable expansion of a confined portion of air.   To prepare it, a glass tube is to be provided, eighteen inches long, open at one end, and blown into a ball at the other.   On applying a warm hand to the ball, the included air expands, and a portion is expelled through the open end of the tube.   In this state the aperture is quickly inverted in a cup filled with any coloured liquid, which ascends into the tube as the air in the ball contracts by cooling.   The instrument is now prepared.   An increase of temperature forces the liquor down the tube ; and on the contrary, the application of cold causes its ascent.   These effects may be exhibited alternately by applying the hand to the ball, and then blowing on it with a pair of bellows.   By the application of a graduated scale, the amount of expansion may be measured.

The advantage of the *Air Thermometer* consists in the great amount of the expansion of air, which by a given elevation of temperature, is increased in bulk above twenty times more than mercury.   Hence it is adapted to detect minute changes, which the mercurial thermometer would scarcely discover ; and its expansions being uniform for equal additions of caloric, it is better adapted than any liquid for becoming, when properly applied, an accurate measure of temperature. But an insuperable objection to it, in its present form is, that it is affected not only by changes of temperature, but by variations of atmospheric pressure.

Differential Thermometer.   An ingenious modification of the air thermometer was invented by Prof. Leslie and employed by him, with great advantage in his interesting researches respecting heat.   To this instrument he gave the name of the *Differential Thermometer*.   It consists of two thin glass balls joined together by a tube bent nearly into the shape of the letter U.   Both balls contain air, but the greater part of the tube is filled with sulphuric acid coloured with carmine.   It is obvious that this instrument cannot be affected by any change of temperature acting equally on both balls; for as long as the air within them expands or contracts to the same extent, the pressure on the opposite surfaces of the liquid, and consequently its position, will continue unchanged.   Hence the differential thermometer stands at the same point, however different may be the temperature of the medium.   But the slightest difference between the temperature of the two balls will instantly be detected ; for the elasticity of the air on one side being then greater than that on the other, the liquid will retreat towards the ball whose temperature is lowest.   It is hence admirably adapted to ascertain the difference of the temperatures of two contiguous spots in the same atmosphere ; for example, to determine the heat in the focus of a concave reflector.—*See Leslie's Essay on Heat.*

The differential thermometer of the late Dr. Howard of Baltimore, resembles that of Prof. Leslie in its general form, but the degree of heat is measured by the expansive force of the vapour of ether or alcohol *in vacuo*. It is intended to be applied to the same purposes as that of Prof. Leslie, but is a much more delicate instrument.—*Brande's Jour.* viii. 219.

Alcohol and Mercurial Thermometers.—Thermometers filled with alcohol or spirit of wine, (a liquid which has not been congealed by any degree of cold hitherto produced,) are best adapted to the measurement of very low temperatures, at which mercury would freeze. The amount of the expansion of alcohol, also, which exceeds that of mercury above eight times, fits it for ascertaining very slight variations of temperature. But it cannot be applied to measure high degrees of heat, because the conversion of the spirit into vapour would burst the instrument.—*Henry,* i. 96.

The fluid best adapted for filling thermometers is mercury, which, though it expands less in amount than air or alcohol, still undergoes this change to a sufficient degree; and in consequence of its difficult conversion into vapour, may be applied to the admeasurement of more elevated temperatures.

In the construction of thermometers the first object is to select a tube with a small bore, the diameter of which is the same throughout its whole length; and then by melting the glass to blow a bulb at one end of it. The bulb is now heated, by means of which the air within it is rarified; and the open end of the tube is dipped into mercury. As the air cools and contracts, the mercury is forced up, entering the bulb, to supply the place of the air which has been expelled from it. Only a part of the air, however, is removed by this means; the remainder is driven out by the ebullition of the mercury.

Having thus contrived that the bulb and about one-third of the tube shall be full of mercury, the next step is to seal the open end hermetically. This is done by heating the bulb till the mercury rises very near the summit, and then suddenly darting a fine pointed flame from a blowpipe across the opening, so as to fuse the glass and close the aperture, before the mercury has had time to recede from it.

The graduation of the thermometer, by which alone the observations made with different instruments can be compared together, consists of two parts, viz. first, to obtain two fixed points which shall be the same in every thermometer: and second, to divide the interval between these two fixed points into any number of equal parts or degrees. To effect the first of these objects, the practice generally pursued, is that introduced by Sir Isaac Newton, and is founded on the fact that when a thermometer is plunged into ice that is dissolving, or into water that is boiling, it constantly stands at the same elevations in all countries, provided there is a certain conformity of circumstances. The point of congelation, or the freezing point, is ascertained by immersing, in thawing snow or ice, the ball and part of the stem; so that the mercury when stationary, shall barely appear above the surface. At this place let a mark be made with a file.

To fix the boiling point is a more delicate operation, since the temperature, at which water boils is affected by various circumstances, which will be more particularly mentioned hereafter. The general directions are, that the water be perfectly pure, free from any foreign particles, and not above an inch in depth—the ebullition brisk, and

conducted in a deep metallic vessel, so that the stem of the thermome-
ter may be surrounded by an atmosphere of steam, and thus exposed to
the same temperature as the bulb—that the vapour be allowed to escape
freely—and the barometer to stand at 30 inches.

The second part of the process, or the division of the interval be-
tween the two fixed points, may be effected by marking on the tube it-
self, by means of a diamond, or by first drawing the divisions upon a
piece of paper, ivory or metal, and afterwards attaching it to the ther-
mometer. The number of divisions between these two points is not
material, though it would be more convenient if there was greater
uniformity in this respect. In the centigrade thermometer, which is
perhaps the most convenient, this space is divided into 100°, the
freezing of water, being marked 0°, the boiling point 100°. In the
scale of Reaumur the freezing point is 0°, the boiling point 80°. And
in Fahrenheit's scale, generally employed in England and America,
the interval is divided into 180°; but the zero of Fahrenheit is placed
32° below the temperature of melting snow, and on this account the
point of ebullition is 212°. The temperature expressed by one of these
scales can easily be reduced to that of another, by knowing the rela-
tion which exists between their degrees.—*See Turner and Webster's
Brande, also L. U. K. Art. Heat.*

REFERENCES. *Particular directions for the construction of Thermo-
meters, Henry's Chem.* i. 96. *The Chevalier Landriani's directions for
constructing Thermometers of great sensibility, Brande's Jour.* vii. 183.
*Directions for determining the accuracy of Thermometers, Faraday's
Chem. Manip. Library of Useful Knowledge, Thermometer and Pyro-
meter. The article Thermometer in the Edinburgh Encyclopædia. Prof.
Forbes' Report on Meteorology, to the British Association,* 1832.

Pyrometers. These are instruments for measuring degrees of heat
much higher than those which can be determined by the mercurial
thermometer. Of these, there are several. That of Mr. Wedgewood
is founded upon the property which clay possesses of contracting when
strongly heated, without returning to its former dimensions as it cools.
But the indications of this instrument cannot be relied on, and it is at
present, seldom employed. The best pyrometer is perhaps that of Mr.
Daniell. A bar of platinum is enclosed in a case made of the same
ware as black lead crucibles, and is fixed to it at one end, while the
other is left free to move an index, by which means degrees of heat,
above ignition, admit of being measured, but not with accuracy, owing
to the increasing rate of expansion in metals at high temperatures.—
Henry, i. 92. *Brande's Jour.* xi. 309.

On the same principle Breguet has constructed a very sensible me-
tallic thermometer, for temperatures between the freezing and boiling
points of water. It consists of a slip of silver and another of platinum,
united face to face with solder, and coiled into a spiral, one end of
which is fixed, while the other is connected with an index which moves
over a circular graduated plate. Strictly, two metals only are suffi-
cient for the purpose, platinum and silver, for instance; but it has been
found to be an improvement to employ three, and the instrument is
now prepared by interposing between the platinum and silver a metal
of mean dilatibility, such as pure gold. The unequal expansion of
the metals causes the spiral to increase or diminish the degree of its
curvature by variations of temperature; and the needle, being attach-
ed at right angles to the axis of the spiral, is thus made to traverse the

graduated circle. Experiments have shown that the needle for equal changes of temperature, moves over equal arcs, so that the instrument is comparable, not only with itself, but with others constructed on the same principle. Such was found to be its great sensibility, that, when enclosed in a large receiver, which was rapidly exhausted by the air pump, it indicated a reduction of temperature from 66° F. to 25°, (= 41°,) while a sensible mercurial thermometer, similarly situated, fell only 3.6°.—*Henry's Chem.* i. 92. *Ann. de Chim. et de Phys* .v. 312.

Instruments have also been constructed for the purpose of ascertaining the highest and lowest temperature which has occurred during a given interval of time. These have been called *Register Thermometers;* and one of the best is that described by Dr. John Rutherford.—*Turner's Chem. and L. U. K.*

But though the thermometer is one of the most valuable instruments of philosophical research, it is by no means an exact measure of the number of degrees of heat in a body. It does not follow, because the thermometer stands at the same elevation in any two bodies, that they contain equal quantities of caloric ; nor should we infer that the warmer possesses more of this principle than the colder. The thermometer only indicates that condition of a body which is expressed by the term *temperature.* All that we learn by this instrument is, whether the temperature of one body is greater or less than that of another ; and the difference, if there be any, is expressed numerically, namely by the degrees of the thermometer. These degrees, however, it should be remembered, are merely parts of an arbitrary scale which have no reference whatever to the actual quantity of caloric present in bodies.

REFERENCES. *Wedgewood's description of and observations on his Pyrometer, Repertory of Arts, 1st series,* v. vi. vii. ix. *Gazeran's Memoirs on the method of preparing the Pyrometrical Earths of Wedgewood, Same work 1st series,* xiv. 211. *Fourmy on the Thermometer of baked Earth, Same work, 2d series,* vii. 143. xxii. 309. *L. U. K.*

LIQUEFACTION.

It has already been shown, that as we apply heat to a body, it increases in bulk. In continuing its application, the enlargement also continues, till the body arrives at a certain temperature, when a change of a different nature ensues. It now becomes liquid, and is said to be *melted, liquified* or *fused,* and the change is called *fusion,* or *liquefaction.* On the contrary, when we apply cold to a liquid it contracts, and continues to do so till at a certain temperature it becomes solid, and it is then said to be *frozen* or *congealed.* In this way almost every fluid may be made solid, and almost every solid, fluid ; and both these points, though different for different bodies, are uniformly the same under similar circumstances in the same body. Under this head the two following general propositions may be stated :

I. *Bodies in passing from a solid to a liquid state, absorb caloric.*

If a pound of water at 32° be mixed with a pound of water at 172°, the temperature of the mixture will be intermediate between them, or 102°. But if a pound of water at 172° be added to a pound of ice at 32°, the ice will quickly dissolve, and on placing a thermometer in the mixture, it will be found to stand, not at 102°, but at 32°. In this experiment, the pound of hot water, which was originally at 172°, actu-

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ally loses 140° of caloric, all of which entered into the ice, and caused its liquefaction, but did not affect its temperature; and it follows, therefore, that a quantity of caloric becomes insensible during the melting of ice, sufficient to raise the temperature of an equal weight of water 140° F. This explains the well known fact, on which the graduation of the thermometer depends,—that the temperature of melting ice or snow never exceeds 32° F. All the caloric which is added becomes insensible, till the liquefaction is complete.

The loss of sensible caloric which attends liquefaction seems essentially necessary to the change, and for that reason is frequently called the *caloric of fluidity.* The actual quantity of caloric required for this purpose varies with the substance, as is proved by the following results obtained by Irvine. The degrees indicate the extent to which an equal weight of each material may be heated by the caloric of fluidity which is proper to it.

						Caloric of fluidity.
Sulphur	.	.	.	.	.	143.68° F.
Spermaceti	.	.	.	.	.	145
Lead	.	.	.	.	.	162
Beeswax	.	.	.	.	.	175
Zinc	.	.	.	.	.	493
Tin	.	.	.	.	.	500
Bismuth	.	.	.	.	.	550

All the bodies enumerated in this table, require, it may be observed, more caloric to bring them into a fluid state than is sufficient to convert ice into water, for which 140° are sufficient.

Other examples of the absorption of caloric during the liquefaction of bodies, are furnished by the mixture of snow and nitric acid, or of snow and common salt, both of which, in common language, produce intense cold.[*] Crystallized chloride of calcium mixed with snow, in the proportion of three parts of the former, to two of the latter, causes the thermometer to sink to — 50°. Most neutral salts also, during solution in water, absorb much caloric; and the cold thus generated, is so intense as to freeze water and even to congeal mercury.

A most striking illustration of the same general fact occurs when a piece of frozen mercury (the temperature of which is at least 40° below zero) is thrown into a little water; the latent heat of the water immediately passes into the mercury and melts it, but the water is so cooled as to be converted into ice.

For further particulars concerning the frigorific mixtures, the reader is referred to— *Walker on the artificial Production of Cold, Phil. Mag. and Ann.* iii. 401; *Pepys and Allen's Account of Experiments on the production of Cold, in one of which fifty-six pounds of mercury were frozen into a solid mass; Tilloch's Phil. Mag.* iii. 76; *Parkes' Essay on Temperature. A convenient apparatus for freezing mercury is described by Dr. Henry, in the 2d volume of his Chemistry.*

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[*] The Peasants on the Baltic say, that nothing tends so effectually towards the freezing of the sea as a fall of snow into the salt water. The effects of a snow storm are thus described: " The water becomes turbid, like milk turning to curd, pieces of ice soon made their appearance and were heard rattling against the prow and sides of the vessel." *Dr. E. D. Clarke's Travels,* ii. 201, 242.

2. *Liquids in becoming solid, evolve or give out caloric, or in common language, produce heat.*

Water, if covered with a thin stratum of oil, and kept perfectly free from agitation, may be cooled down more than 20 degrees below 32° ; but on shaking it, or dropping into it a small fragment of ice, it immediately congeals, and the temperature rises to 32°.—*Blagden, Phil. Trans.* 1788.

If we dissolve sulphate of soda in water, in the proportion of one part to five, and surround the solution by a freezing mixture, it cools gradually down to 31°. The salt at this point begins to be deposited, and stops the cooling entirely. This evolution of caloric, during the separation of a salt, is exactly the reverse of what happens during its solution.—*Blagden.*

To a saturated solution of sulphate of potassa or sulphate of magnesia in water, add an equal measure of alcohol. The alcohol, attracting the water more strongly than the salt does, precipitates the salt, and considerable heat is produced.

These phenomena are all easily explained by Dr. Black's doctrine of *latent heat.* According to this doctrine, caloric in causing fluidity loses its property of acting on the thermometer, in consequence of combining chemically with the solid substance, and liquefaction results because the compound so formed does not possess that degree of cohesive attraction on which solidity depends. When a liquid is cooled to a certain point, it parts with its caloric of fluidity, heat is set free, or becomes sensible, and the cohesion natural to the solid is restored.

VAPORIZATION.

This effect of caloric is conveniently studied under two heads—*Ebullition* and *Evaporation.* In the first, the production of vapour is so rapid that its escape gives rise to a visible commotion in the liquid ; in the second, it passes off quietly and insensibly.

Ebullition. The temperature at which vapour rises with sufficient freedom for causing the phenomena of ebullition, is calling the *boiling point.* The heat requisite for this effect varies with the nature of the fluid. Thus, sulphuric ether boils at 96° F. alcohol at 173°, and pure water at 212° ; while oil of turpentine must be raised to 316°, and mercury to 680°, before either exhibits marks of ebullition. The boiling point of the same liquid is constant, so long as the necessary conditions are preserved ; but it is liable to be affected by several circumstances. The nature of the vessel has some influence upon it. Thus, Gay Lussac observed that pure water boils precisely at 212° in a metallic vessel, and at 214° in one of glass. It is likewise affected by the presence of foreign particles. The same accurate experimenter found, that when a few iron filings are thrown into water boiling in a glass vessel, its temperature quickly falls from 214° to 212°, and remains stationary at the last point.

But the circumstance which has the greatest influence on the boiling point of fluids is the variation of atmospheric pressure. In reference to this subject the following propositions may be stated.

1. *When atmospheric pressure is diminished, fluids boil at a lower temperature than under the ordinary pressure.* Thus water which has been removed from the fire, and has ceased to boil, has its ebullition renewed, when it is placed under a receiver, the air of which is quickly ex-

hausted by an air pump. Alcohol and ether, confined under an ex-
hausted receiver, boil violently at the temperature of the atmosphere.
In general, liquids boil, *in vacuo*, with about 140° less of heat than are
required under a mean pressure of the atmosphere. [*Black's Lecture's*
i. 151.] Water therefore in a vacuum must boil at 72°, alcohol at 36°,
and ether at — 44° F.

The influence of a diminished pressure in causing ebullition to take
place at a lower temperature, may also be shown as follows:

Exp. Fill a barometer tube with mercury and invert it in a basin of
the same fluid : then pass up a small quantity of ether by means of a
half ounce phial. The ether upon reaching the torricellian vacuum
immediately springs into vapour and forces the mercury down the tube.
If the tube is inclined, the ebullition ceases.

Exp. Place over a lamp a Florence flask, about three-fourths filled
with water : let it boil briskly during a few minutes; and immediate-
ly on removing it from the lamp, cork it tightly, and suddenly invert
it. The water will now cease to boil : but on cooling the convex part
of the flask, by a stream of cold water, the boiling will be renewed.
Applying boiling water to the same part of the flask, the water will
again cease to boil. This renewal of the ebullition by the application
of cold, (an apparent paradox,) is owing to the formation of an imper-
fect vacuum over the hot water, by the condensation of steam; and
the suspension of boiling, on reapplying the heat to the renewed pres-
sure on the surface of the hot water, occasioned by the formation of
fresh steam.

The same fact is illustrated by the common pulse glass, in which the
fluid is made to boil by the mere heat of the hand.

2. *When atmospheric pressure is increased, fluids require a higher tem-
perature to produce their ebullition.*

Water cannot be heated under common circumstances beyond 212°,
because it then acquires such an expansive force as enables it to over-
come the atmospheric pressure, and fly off in the form of vapour. But
if subjected to sufficient pressure, it may be heated to any extent with-
out boiling. This is best done by heating water while confined, in a
strong copper vessel, called Papin's Digester. In this apparatus, on
the application of heat, a large quantity of vapour collects above the
water, which checks the ebullition by the pressure it exerts upon the
surface of the liquid. There is no limit to the degree to which water
may be heated in this way, provided the vessel is strong enough to con-
fine the vapour; but the expansive force of steam under these circum-
stances is so enormous as to overcome the greatest resistance.

An apparatus for exhibiting the same fact, has been contrived by Dr.
Marcet, of which a figure and description will be found in *Webster's
Brande and Henry's Chem.* i. 126.

It should be observed, that during the conversion of a liquid into va-
pour, caloric is absorbed. This is proved by the well known fact, that
the temperature of steam is precisely the same as that of boiling water
from which it rises, so that all the caloric which enters into the liquid
is solely employed in converting a portion of it into vapour, without
affecting the temperature of either in the slightest degree, provided the
latter is permitted to escape with freedom. On the other hand, when
this vapour is condensed into water, the caloric which was latent, ac-
cording to the explanation of Dr. Black, becomes free. The exact
amount of caloric rendered latent by vaporization, may therefore be as-

certained by condensing the vapour in cold water and observing the rise of temperature occasioned by it. From the experiments of Dr. Black and Mr. Watt, conducted on this principle, it appears that steam of 212°, gives out as much caloric as would raise the temperature of an equal weight of water by 950 degrees, all of which had previously existed in the vapour without being sensible to a thermometer.

The latent heat of the vapours of different liquids has been investigated by Dr. Ure, and by M. Despretz. From the results, Dr. Ure has constructed a table. [See his *Dictionary of Chemistry.*]

The only fluid, the vapour of which can be converted to any particular use, is water. Owing to the heat which it gives out when condensed into steam, it is often used for heating large quantities of water. It is also employed for heating rooms and for carrying on different chemical processes, in which too great heat would be injurious, as in assisting fermentation and in drying substances gradually, and without the risk of burning.

In consequence of the great elasticity of steam, it is employed as a moving power in the steam-engine. The construction of this machine depends on two properties of steam, namely, the expansive force communicated to it by caloric, and its ready conversion into water by cold. The effect of both these properties is well shown by a little instrument devised by Dr. Wollaston. It consists of a cylindrical glass tube, six inches long, nearly an inch wide, and blown out into a spherical enlargement at one end. A piston is accurately fitted to the cylinder, so as to move up and down the tube with freedom. When the piston is at the bottom of the tube, it is forced up by causing a portion of the water, previously placed in the ball, to boil by means of a spirit-lamp. On dipping the ball into cold water, the steam which occupies the cylinder is suddenly condensed, and the piston forced down by the pressure of the air above it. By the alternate application of heat and cold, the same movements are reproduced, and may be repeated for any length of time.

The moving power of the steam-engine is the same as in this apparatus. The only essential difference between them is in the mode of condensing the steam. In the steam-engine, the steam is condensed in a separate vessel, called the *condenser*, where there is a regular supply of cold water for the purpose. By this contrivance, which constitutes the great improvement of Watt, the temperature of the cylinder never falls below 212°.— *Turner.*

REFERENCES. *For a table of the boiling points of the most important liquids, see Ure's Dict. of Chem. and L. U. K. art. Heat,* 50. *Gay Lussac, Muncke and Biot, on the fixedness of the boiling point of Fluids, Ann. of Phil.* xii. 129. *Lardner's Popular Lectures on the Steam-Engine, and Professor Renwick's Treatise on the same subject.*

Evaporation. Evaporation as well as ebullition consists in the formation of vapour, and the only assignable difference between them is, that the one takes place quietly, the other with the appearance of boiling. Evaporation takes place at common temperatures, as may be proved by exposing water in a shallow vessel to the air for a few days, when it will gradually diminish, and at last disappear entirely. Most fluids, if not all of them, are susceptible of this gradual dissipation ; and it may also be observed in some solids, as for example, in camphor. Evaporation is much more rapid in some fluids than in others, and it is always found that those liquids, whose boiling point is the

lowest, evaporate with the greatest rapidity. Thus alcohol, which boils at a lower temperature than water, evaporates also more freely; and ether, whose point of ebullition is lower than that of alcohol, evaporates with still greater rapidity.

The chief circumstances that influence the process of evaporation are extent of surface, and the state of the air as to temperature, dryness, stillness, and density.

As a large quantity of caloric passes from a sensible to an insensible state during the formation of vapour, it follows that cold should be generated by evaporation. A very simple experiment will prove it. If a few drops of ether be allowed to fall upon the hand, a strong sensation of cold will be excited during the evaporation ; or if the bulb of a thermometer, covered with lint, be moistened with ether, the production of cold will be marked by the descent of the mercury.* But to appreciate the degree of cold which may be produced by evaporation, it is necessary to render it very rapid and abundant by artificial processes ; and the best means of doing so, is by removing pressure from the surface of volatile liquids. Water placed under the exhausted receiver of an air pump, evaporates with great rapidity, and so much cold is generated as would freeze the water, did the vapour continue to rise for some time with the same velocity. But the vapour itself soon fills the vacuum, and retards the evaporation by pressing upon the surface of the water.† This difficulty may be avoided by putting under the receiver a substance, such as sulphuric acid, which has the property of absorbing watery vapour, and consequently of removing it as quickly as it is formed. Such is the principle of Mr. Leslie's method for freezing water by its own evaporation.—*Edinburgh Encyclopedia, art. Cold. See also Dr. Cullen on the Cold produced by Evaporation, Edinburgh Physical and Literary Essays*, ii. 159.

The action of the Cryophorus, an ingenious contrivance of Dr. Wollaston, depends on the same principle. It consists of two glass balls, perfectly free from air, and joined together by a tube. One of the balls contains a portion of distilled water, while the other parts of the instrument, which appear

* The production of cold during evaporation, is by no means confined to the more volatile liquids. Kœmpfer states, that on the borders of the Persian Gulf the winds are so scorching, that travellers are suddenly suffocated, unless they cover their heads with a wet cloth ; but if this be too wet, they immediately feel an intolerable cold, which would become fatal to them if the moisture were not speedily dissipated by the heat. The cold, which is produced by the act of evaporation, ceases as soon as that is finished, by the cloth becoming dry.— *Watson's Chem. Essays*, iii. 126. Wet clothes also are injurious, because the evaporation produces cold on the surface and thus constricts the extreme vessels.

† In Glasgow and the neighbourhood, soda and alum leys are brought to the requisite degree of concentration, by passing over their surface a brisk current of air which has previously passed through a fire ; so that the flame of the fire plays over the surface of the evaporating liquor. And this process has been found more convenient and economical, than the method of evaporating liquids by applying heat to the bottom of vessels containing them.— *Thomson's Outline of Heat, &c.* 243.

empty, are full of aqueous vapour, which checks the evaporation from the water by the pressure it exerts upon its surface. But when the empty ball is plunged into a freezing mixture, all the vapour within it is condensed; evaporation commences from the surface of the water in the other ball, and it is frozen in two or three minutes by the cold thus produced.—*Phil. Trans.* 1813.

Liquids which evaporate more rapidly than water, cause a still greater reduction of temperature. The cold produced by the evaporation of ether in the vacuum of the air-pump, is so intense as under favorable circumstances to freeze mercury. Advantage has also been taken of this circumstance in Mr. Howard's plan for refining sugar, and in plans for preparing pharmaceutical extracts *in vacuo.*—*Repertory of Arts,* 2d *Ser.* xxiii. & xxv.

Concerning the cause of evaporation a difference of opinion exists among chemists. It was at one time supposed to be owing to a chemical attraction between the air and water. But Mr. Dalton has shown that caloric is the true and the only cause of the formation of vapour. As our limits do not permit us to enter into these discussions we shall refer the reader to—*Turner's Chemistry ; Henry's Chem ; Dalton, in Manchester Memoirs,* v.; *Ure, in Phil. Trans.* 1818 ; *Biot's Traité de Phys.* 1. ; *Faraday on the existence of a limit to Vaporization, Phil. Trans.* 1826.

The presence of watery vapour in the atmosphere, is owing to evaporation which takes place from the water on the surface of the earth. As this evaporation goes on to a certain extent, even at low temperatures, it is probable that vapour is always present in the air, though its quantity is subject to great variation, in consequence of the changes of temperature to which the air is constantly subjected. But even when the temperature is the same, the quantity of vapour is still found to vary ; for the air is not always in a state of saturation. At one time it is excessively dry ; at another it is fully saturated; and at other times it varies between these extremes. Instruments have been constructed to determine this variable condition of the atmosphere as to saturation, which are called *Hygrometers.* These consist for the most part of some substance, such as human hair, or a fine slip of whale bone, which is elongated by a moist atmosphere, and shortened by a dry one. The extreme points are attained by placing it, first in air artifically dried, and then in air rendered as humid as possible. The degree of expansion or contraction is rendered more sensible by connecting it with an axis, which moves a circular index, like the finger of a clock. Mr. Leslie, by a slight modification of his differential thermometer, makes it serve the purpose of an hygrometer : for if one of the balls be covered with silk, and then moistened with water, the rate of evaporation will be shown by the degree of cold produced, as indicated by the descent of the liquid in the opposite leg of the instrument. The drier the air, the quicker will be the evaporation, and the greater the effect in moving the liquid within the instrument.—*Henry,* i. 280.

But the most perfect instrument of this kind, is that invented by Mr. Daniell, for a particular description of which the reader is referred to *Daniell's Meteorological Essays*—or to the Library of Useful Knowledge, art. *Pyrometer and Thermometer,* where several modifications of the *Hygrometer* are also described. For information on the subject of Hygrometers, see alro *Prof. Forbes' Report on Meteorology, made to the Brit. Ass. in* 1832. I should also mention that Mr. A.

Hayes has described a dew-point Hygrometer in—*Silliman's Journal*, xvii. 351.

SECTION V.

SPECIFIC CALORIC.

Equal weights of the *same* body at the *same* temperature, contain the same quantity of caloric. But equal weights of *different* bodies at the same temperature, contain unequal quantities of caloric. Thus if we add a pint of water at 100° F. to a pint of the same liquid at 50°, the mixture will have a temperature of 75°, or the mean between the two; that is, the 25° which the hot water has lost, has been just sufficient to raise the cold by as many degrees. But if one pound of mercury at 185° F. is mixed with a pound of water at 40°, the mixture will have a temperature 45° only; or if the experiment be reversed by having the water at 185° and the murcury at 40°, the mixture will have a temperature of 180°. In the first case, 140 degrees lost by the mercury served to heat the water by five degress, and in the second, five degrees lost by the water sufficed to raise the temperature of the mercury by 140°. It hence appears that 28 times more caloric is required to raise the temperature of water through one or more degrees, than for heating an equal weight of mercury to the same extent.

By mixing water with various other substances it has been found that it requires different quantities of caloric to heat them equally. Thus on the addition of warm water to a jar containing a pound of water at 50°, the temperature will rise, say 10°; on adding a similar quantity of warm water to another jar containing a pound of spermaceti oil, it will rise 20°; and the same addition to a jar containing a pound of powdered glass will cause a rise of 50°.

Here then it will be observed that eqaul quantities of caloric added to water, oil, and glass, have raised the temperature of the first 10, of the second 20, and of the third 50 degrees. Now it is clear that if we wished to raise them all to the same temperature, say 50°, we must add twice and a half as much to the oil, and five times as much to the water. The quantities of caloric which they are capable of receiving, are therefore as glass 10, oil 20, water 50; or taking water as the standard, and calling it 1000, they are water 1000, oil 500, glass 200.

The term employed, to designate this remarkable difference, by Dr. Black, who first observed it, was *capacity for caloric*. But as this term is apt to lead to erroneous impressions concerning the cause of this difference, that of *specific caloric* has been substituted for it, and is now generally employed.

When substances can be mixed together, as in the instances above mentioned, their specific caloric can be determined, by ascertaining the relative quantities of caloric which is requisite for heating them by an equal number of degrees. Water is commonly employed as one of the substances, and the specific caloric of other bodies is usually compared with that of water.

In some cases, however, the bodies under examination cannot be intimately mixed. When the specific heat of a solid mass of metal is to be examined, it may be heated throughout to a certain degree, and then surrounded by water, at 32°, observing the increase of temperature

which is gained by the water, and calculating the specific heat as before. This was the method of Wilcke, of Stockholm.—[*Thomson's Chem.* i. 100.] Lavoisier and La Place substituted ice for water, placing, by means of an apparatus called the *Calorimeter*, the heated body in the centre of a quantity of ice, and determining the caloric evolved, by the quantity of ice melted in each instance.—*Lavoisier's Elements.*

It has been ascertained by Petit and Dulong, who have recently investigated this subject, that the specific heats of bodies are greater at high than at low temperatures. They have also deduced from their researches the law, that *the atoms of all simple bodies have precisely the same specific heat.*—[*Ann. of Phil.* v. 13.] This, however, is to be considered at present, merely in the light of an ingenious speculation, derived from a train of reasoning, a defect in any part of which must be fatal to the conclusions. *See Henry,* i. 160; *Dalton's New Syst.* ii. 280; *Also, Professor Bache's Strictures on the Table of Petit and Dulong, Jour. of the Acad. of Nat. Scien. Phil. Jan.* 1829.

The determination of the specific heat of gases has successively engaged the attention of some of the most profound and ingenious chemical philosophers. Among the most valuable observations on this subject, are those of Delaroche and Berard, De La Rive and F. Marcet. In the experiments of the two latter philosophers which are the most recent, they appear to have avoided sources of fallacy which were not provided against by those who preceded them in these investigations. From a review of their experiments, they consider the following conclusions as legitimately deducible.

1. That under the same pressure, and with equal and constant volumes, (the elasticity alone varying,) all gases have the same specific heat.

2. That, all other circumstances remaining the same, the specific heat diminishes at the same time as the pressure, and equally for all gases, according to a progression but little convergent, and in a much less ratio than that of the pressures.

3. That each gas has a different power of conducting heat.—*Henry's Chem.* i. 163.

REFERENCES. *For tables of the Specific Heats of some Gases, see Library of Useful Knowledge, Art. Heat, or Thomson's Outline of Heat, &c.* 71. *Delaroche and Berard on the Specific Heat of Gases, Ann. of Phil.* ii. *Herepath on the causes of Heat in Gases, Ann. of Phil.* xvii. *Same author's Tables of Temperature,' and replies to him, Ann. of Phil.* xvii. & xviii. *Meikle on the Specific Heat of Air. Edin. New Phil. Jour.* ii. 328.

SECTION VI.

SOURCES OF CALORIC.

The sources of caloric may be reduced to six, viz.

1. THE SUN,	4. MIXTURE,
2. FRICTION,	5. ELECTRICITY,
3. PERCUSSION,	6. COMBUSTION.

1. *The Sun.* The heat produced by the sun is found to differ according to the surface exposed, and the colour of the surface. Franklin found that when pieces of cloth of various colours were exposed upon snow to the light of the sun, they sunk deeper, and consequently acquired heat, in proportion to the darkness of their colour. This experiment was repeated with more precision by Sir H. Davy, with similar results.

The temperature produced by the direct action of the sun's rays seldom exceeds 120°; a higher temperature, however, may be produced if we prevent the heat communicated from being carried off to surrounding bodies.

But when the sun's rays are concentrated by means of a burning lens, intense heat is produced, provided they are directed upon some body capable of absorbing and retaining them. Some lenses have been constructed of extraordinary power, and among them may be mentioned those of Tschirnhausen and M. de Trudaine, by which many of the most refractory substances were readily fused. [For a description of these and other powerful lenses, see *Chaptal's Chem. app. to the Arts, and Parkes' Chem. Essays.*] According to Count Buffon, however, the only way by which the sun's rays can be made to produce an intense heat at a great distance, is by the combination of a considerable number of plain mirrors, so disposed as to throw numerous images of the sun upon the same spot. By an instrument constructed upon this principle he was enabled to melt the metals and metallic minerals at the distance of forty feet, and to kindle wood when at the distance of 210 feet.—*Parkes' Chem. Essays.*

2. *Friction.* Fires are often kindled by rubbing pieces of dry wood smartly against one another. So also when parts of heavy machinery rub against one another, the heat excited, if the parts in contact are not well greased, is sufficient for kindling wood. The axle-tree of carriages has been burned from this cause, and the sides of ships are said to have taken fire by the rapid descent of the cable.—[*Parry's 2d Voyage, N. Y. Ed.* 212.] Count Rumford observed, that in the boring of cannon, by the friction of the borer, a very large quantity of caloric is rendered sensible. To ascertain its quantity, he fixed a solid cylinder of brass in a trough filled with water, and having adapted the borer to it, connected with the machinery by which it is turned, it was made to revolve in the usual manner, at the rate of 32 times in a minute. Heat was soon excited, and of course raised the temperature of the metal, and of the surrounding water. In an hour the temperature had risen from 60 to 107°; and in two hours and a half the water was brought to boil, the quantity of this water being 18 lbs.; the apparatus itself, which was of course raised to the same temperature, weighed 15 lbs.

From this experiment it may be safely concluded, that the access of atmospheric air is not essential to the evolution of caloric; an inference confirmed also by the experiment of Pictet—who constructed an apparatus by which friction could be excited in an exhausted receiver. The thermometer rose higher than when this friction was going on in open air.—*Rumford's Essays. Pictet's Essay on Fire.*

It was hence concluded by these philosophers that caloric was not a material substance, but a kind of motion. The same opinion was adopted by Sir H. Davy. But although these facts present a difficulty in the adoption of the hypothesis that caloric is material, the other

phenomena can be more satisfactory explained upon the latter supposition, and hence it is quite generally adopted by the chemists of the day. —*See references under the first Section of this Chapter.*

3. *Percussion.* The heat excited by percussion is equal, and in many cases superior, to that evolved by friction. When a piece of iron is smartly and quickly struck with a hammer, it becomes red hot; and another familiar illustration is the production of heat by the compression of air in the common fire-syringe. No heat, however, has been observed to follow the percussion of liquids, nor of soft bodies which easily yield to the stroke.

4. *Mixture.* We have already given some examples of the effect of mixture in producing heat; as in the case of the mixture of sulphuric acid and water, and the mixture of sulphuric acid with the chlorate of potash and sugar. [See page 24.] So also some gaseous bodies, which, when united together, form solids, as ammoniacal and muriatic acid gases, evolve a considerable degree of heat. Sometimes however, the temperature of the mixture is reduced, and the sensation of cold produced; as is remarkably the case in some of the freezing mixtures.

It may be laid down as a rule, to which there are few exceptions, that when the compound formed by the union of two bodies is more fluid or dense than the mean fluidity or density of the two bodies before mixture, then the temperature sinks; but when the fluidity or the density of the new compound is less than that of the two bodies before mixture, the temperature rises; and the rise is pretty nearly proportional to the difference.— *Thomson's Chem.* i. 143.

5. *Electricity.* This will be particulary noticed in Chapter IV.

6. *Combustion.* This may be defined to be the disengagement of heat and light which accompanies chemical action.

Modern discoveries have shown the insufficiency of former theories upon this subject. But in the present state of our knowledge, we are unable to substitute one that is wholly free from objection; and we are left to the naked statement of the fact, that combustion is the *general* result of the actions of any substances which possess strong chemical attractions, or different electrical relations.— *Ure's Chem. Dictionary.*

I shall notice the leading phenomena of combustion under the following heads, viz.

1. The temperature necessary to inflame different bodies.

2. The nature of flame.

3. The heat given out by different combustibles in burning.

4. The causes which modify, promote or extinguish combustion.

1. *The temperature necessary to inflame bodies.* The temperature necessary for inflammation, is very different in different bodies. Thus, if we heat phosphorus to 150° F. it takes fire; but sulphur requires a heat of 500° for its inflammation.

The successive combustibilities of bodies can be shown as follows:

Exp. Into a long bottle with a narrow neck introduce a lighted taper, and let it burn till it is extinguished. Carefully stop the bottle and introduce another lighted taper. It will be extinguished before it

reaches the bottom of the neck. Then introduce lighted sulphur. This will burn for some time; and after its extinction, phosphorus will be as luminous as in the air, and if it be heated will burn with a pale yellow flame.

The combustibilities of various gaseous bodies are to a certain extent as the masses of heated matter required to inflame them. Thus, an iron wire 1-40th of an inch in diameter, heated to a cherry red, will not inflame olefiant gas, but it will inflame hydrogen. A wire of 1-8th of an inch, heated to the same degree, will inflame olefiant gas. But a wire 1-500th of an inch, must be heated to whiteness to inflame hydrogen, though at a low red heat it will inflame bi-phosphuretted gas.

2. *Nature of flame.*—Flame is the rapid combustion of volatilized matter, or in other words, volatile combustible matter heated so highly as to become luminous. Davy has asserted that the flame of combustible bodies must be considered as the combustion of an explosive mixture of inflammable gas or vapour and air, and that this combustion takes place in the interior, as well as at the surface of contact. A simple experiment, however, proves that no combustion goes on in the interior of a flame.

Exp. Place a piece of coin or metal upon an earthen plate; place a small piece of phosphorus upon the coin, and surround the latter with alcohol. The alcohol may be fired without setting fire to the phosphorus, which remains unaffected in the interior of the flame, but as soon as the external air comes in contact with it, combustion instantly takes place.

The interior of a flame consists of aqueous vapour, which may be exhibited by an ingenious apparatus contrived by Mr. Blackadder.—*Edin. New Phil. Jour.* i. 224.

The light of a flame may be shown by the prism to consist of several colours. The flame of a candle consists of four portions, although these may be considerably modified by various circumstances. A blue portion which extends from the base to about the middle of the flame;—an attenuated opaline brush over the whole exterior surface of the blue part of the flame; a cone of yellowish white light, commencing on the inner surface, and at a short distance from the base of the blue portion; and an interior cone of white light, the base of which is above the upper part of the blue portion.—*Edin. New Phil. Jour.* i. 228.

Flame has electric polarity; that of burning phosphorus being acid, is bent towards the positive pole, and that of a candle containing ignited carbon, toward the negative.—*Brande, Phil. Trans.* 1814, *noticed in Ann. of Phil.* iv. 441.

The products of flame are usually water and carbon.

The use of a wick is to raise the fluid by capillary attraction. It is not, however, an essential part of the oil or alcoholic lamp. Lamps without wicks have been constructed by Mr. Blackadder, and are supposed by him to possess many advantages.—*Edin. New Phil. Jour.* i. 52.

The colour of flame depends upon the presence of various foreign substances, and an attention to it is of great utility in many analytical researches. Thus the flame of alcohol is tinged with a fine carmine red by nitrate of strontia, yellow by nitrate of baryta, green by nitrate of copper, &c. This is by some supposed to be owing to the reduction of the substances employed, to the metallic state.

Flame is supposed to possess a very high temperature. By Sir H. Davy it was estimated at 7000° F. But there can be no doubt that the temperature varies with the combustible, and that it is influenced also by other circumstances; and it perhaps never reaches the point first mentioned. One of the arguments advanced by Davy, viz. that a fine platina wire becomes white hot in a part of the flame of a spirit lamp where there is no visible light, has been weakened by the fact since discovered, that the mere contact of a jet of hydrogen with spongy platina causes the incandescence of the latter. The other argument of Davy appears also open to objection.

3. *Heat given out by different combustibles in burning.* On this subject experiments have been made by Lavoisier, Crawford, Dalton, Rumford, and Davy. But the results of these experiments are so discordant that they can scarcely afford any correct guide. They appear to agree, however, that of the numerous substances tried, hydrogen gives out the most heat and carbonic oxide the least.—*Ure's Chem. Dictionary.*

With respect to the heat given out by ordinary combustibles used as fuel, the experiments of Mr. Bull, of Philadelphia, are the most satisfactory. The following results are extracted from his table, in the Transactions of the American Philosophical Society, *N. S.* iii. 1.

Amount of heat given out by various combustibles—a cord of shell-bark hickory being equal to 100.

Shell-bark hickory	100
White oak	81
Hard maple	60
White beech	65
White pine	42
Lehigh coal (a ton 2240 lbs.)	99
Lackawaxen coal	99
Schuylkill coal	103

4. *Causes which modify, promote, or extinguish combustion.* Although the progress of discovery has shown that the generalization proposed by Lavoisier, viz. that in all cases of combustion, oxygen combines with the burning body, is not of universal application; it must be confessed that in most cases the presence of oxygen is essential to the process of combustion. In ordinary cases, the more complete the access of atmospheric air and the more perfect its contact with the combustible, the more perfect will be the combustion. It is upon this principle that most of the modern improvements in the construction of lamps and furnaces depend.

Upon the same principle also the heat may be greatly increased, by causing a blast through a flame. For this purpose, a *blow-pipe*, to be blown either by the mouth or a pair of bellows, is used. The form of this instrument is not material; and several modifications of it have been proposed. The principle upon which it acts, is that a constant supply of air is brought to the inflammable matter, thus rendering the combustion more complete, and the consequent heat greater.

There are other forms of the blow-pipe, as that in which alcohol is employed, and the oxy-hydrogen blow-pipe, which will be noticed hereafter.

Flame being gaseous matter so highly heated as to become lumin-

ous, will be extinguished by a reduction of its temperature. This can be effected by bringing near it some metallic conductor.

Let the smallest possible flame be made by a single thread of cotton immersed in oil, it will be found to yield a flame of about 1-30th of an inch in diameter. Let a fine iron wire of 1-180th of an inch, made into a ring 1-10th of an inch in diameter, be brought over the flame. Though at such a distance, it will instantly extinguish the flame, if it be cold ; but if it be held above the flame, so as to be slightly heated, the flame may be passed through without its being extinguished. That the effect depends entirely on the power of the metal to abstract the heat of the flame, is shown by bringing a glass capillary ring of the same diameter and size over the flame. This being a much worse conductor of heat, will not, even when cold, extinguish it. If its size, however, be made greater, and its circumference smaller, it will act like the metallic wire, and requires to be heated to prevent it from extinguishing the flame.—*Davy on Flame. Ure's Chem. Dictionary.*

It is upon this principle that Sir H. Davy constructed his *Safety Lamp*, one of the most valuable discoveries of the age. In this instrument there is a succession of metallic orifices forming the wire gauze, which constitutes the cage of the lamp, and thus by cooling down the flame prevents it from communicating with the explosive mixture.

The same principle has also been applied by the Chevalier Aldini, to the construction of a robe for the preservation of firemen against fire and flame. [*See Silliman's Jour.* xviii. 177, xx. 96.] M. Libri of Florence ascribes the protection which Davy's lamp affords, to the repulsion exerted by the metallic wire upon the flame.—*Brewster's Edin. Jour.* ix. 311.

REFERENCES. *Graham on the Heat of Friction, Ann. of Phil.* xxviii. 260. *The article Combustion, in Ure's Chem. Dictionary, containing an account of the various theories on this subject ; Also, Thomson's Chemistry. Davy on Flame. Rumford's Experiments on the combustion of Woods, See his Essays, and Thomson's Chemistry. Berzelius on the Blow-pipe. Linton on the colour of Flames, Emporium of Arts,* v. 457. *Porrett's observations on the flame of a Candle, Ann. of Phil.* ix. 337. *Sym on Flame, Ann. of Phil.* viii. 321. *Murray on the same subject, Ann. of Phil.* xvi. 424. *On the construction of Furnaces, and the management of Fuel, See Parkes' Essays ; and also, Gray's Operative Chemist.*

GENERAL REFERENCES ON HEAT. *Count Rumford's Essays. Dalton's New System of Chemical Philosophy. Dr. Black's Lectures, by Robinson. Berthollet's Chemical Statics. Scheele's Treatise on Air and Fire. Leslie's Experimental Inquiry into the Nature of Heat. Pictet's Essay on Fire. Biot's Precis Elémentaire. Murray's System of Chemistry. Thomson's Outline of the Sciences of Heat and Electricity. Library of Useful Knowledge, article Heat. Lavoisier's Elements of Chemistry. Aikin's Dictionary of Chemistry and Mineralogy, article Caloric. Arnott's Physics,* ii. *Lardner on Heat. Depretz, Traité Elémentaire de Physique.* 1837.

CHAPTER III.

LIGHT.

When the sun rises above the horizon a mode of communication is established, which in spite of his great distance, acquaints us with his existence. This mode of communication is called *Light*. And bodies which can thus manifest their existence are said to be *luminous*, (of themselves,) as the sun, the stars, &c. Most bodies, however, as we shall hereafter see, become luminous when their temperature is sufficiently elevated, and they lose this property when they become cool. But even when they become opaque, if enlightened by a luminous body, they acquire the property of transmitting light in the same way as if they were luminous ; and these bodies are said to be visible by *reflection*.

NATURE OF LIGHT.

Concerning the nature of light, philosophers are divided into two classes. The one class consider it to consist of particles of matter actually emanating from the luminous body ; the other conceive it to be transmitted by means of pulsations or vibrations excited in an elastic fluid, in the same way that sound is conveyed through the air. The former opinion was adopted and maintained by Newton, and is now generally received, as best accounting for the phenomena which it exhibits.*

The consideration of the laws of light, so far as they relate to the phenomena of its movement, and its effects in producing vision, constitutes the science of *Optics ;* and are the objects, therefore not of Chemistry, but of Natural Philosophy. I shall, however, briefly notice the physical properties of light, as they bear upon important questions of chemical enquiry.

The light of the sun moves with the velocity of 192,000 miles in a second of time, so that it passes through the whole distance from the sun to the earth in about eight minutes.

Light is transmitted through the air in straight lines, which are called rays of light, and it is by means of these that vision is effected.

When a ray of light falls upon a polished surface, it is thrown off or *reflected*. And the angles of incidence and reflection are in this case always equal, whatever may be the obliquity of the incident ray.

A ray of light passing obliquely from one medium to another, does not proceed in the same direction as before, but is *refracted*, or bent out of its course. If the new medium be denser than the old, the ray

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* Dr. Brewster thus briefly contrasts the two systems. " In the Newtonian theory, light is supposed to consist of material particles emitted by luminous bodies ; and moving through space with a velocity of 192,000 miles in a second. In the undulatory theory, an exceedingly thin and elastic medium, called ether, is supposed to fill all space and to occupy the intervals between the particles of all material bodies."—*Optics*, 134.

of light is bent or reflected nearer to the perpendicular; but in passing out of a denser into a rarer medium, it is refracted from the perpendicular, and there is a constant proportion between the sine of the angle of incidence and that of refraction. Transparent media, also, not only cause a change in the direction of a ray, but decompose it into its constituent parts, an effect which has been called *dispersion.*

When a ray of light, in passing through certain bodies, (Iceland spar for example,) exhibits a double image of any object viewed through them, it is called *double refraction.* In this case the light is divided into two pencils, the one following the law of ordinary refraction; the other being differently affected, constituting extraordinary refraction.

DECOMPOSITION OF LIGHT.

Light is not a simple body, but is capable of being divided by the *prism* into seven primary rays or colours, viz. red, orange, yellow, green, blue, indigo, and violet. These rays differ in their refrangibility, the red being the least, and the violet the most refrangible. These facts can be shown by admitting a ray of light SD into a dark
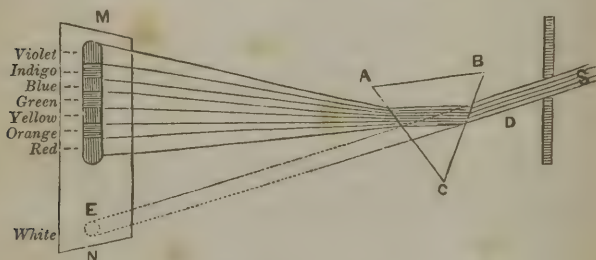
room and interposing the prism ABC, so that the ray passes obliquely through two surfaces and is refracted by both. On receiving the refracted ray upon a piece of white paper MN there appears instead of a spot of white light, an oblong coloured surface, composed of the seven different tints just enumerated, called the *prismatic* or *solar spectrum.*

According to Dr. Wollaston, the sceptrum consists of four colours only, viz. red, green, blue, and violet, and these occupy spaces in the proportion of 16, 23, 36, 25. These different coloured rays being collected by a lens into a focus, again produce colourless light. Again, Dr. Brewster gives a new analysis of solar light indicating three primary colours, forming coincident spectra of equal length.—*Edin. Jour. of Science, N. S.* v. 197.

Sir W. Herschel found that the prismatic colours differ in their *illuminating* powers. The orange possesses this property in a higher degree than the red; and the yellow rays illuminate bodies still more perfectly. The maximum of illumination lies in the brightest yellow or palest green. The green itself is nearly equally bright with the yellow; but from the full deep green, the illuminating power decreases

very sensibly. That of the blue is nearly equal to that of the red ; the indigo has much less than the blue ; and the violet is very deficient.— *Phil. Trans.* 1800.

The *heating* powers of the rays follow a different order. If the bulb of a very sensible thermometer be moved in succession through the differently coloured rays, it will be found to indicate the greatest heat in the red rays; next in the green, and so on, in a diminishing progression to the violet. But when it is removed entirely out of the confines of the red rays, but with its ball still in the line of the spectrum, it rises even higher than in the red rays, and continues to rise, till removed half an inch beyond the extremity of the red rays. It was hence inferred by Herschel, that there exists in the solar beam a distinct kind of ray, which causes heat, but not light ; and that these rays being less refrangible than the luminous ones, deviate in a less degree from their original direction in passing through the prism.

Though the truth of the statement, that the prismatic colours possess different heating powers, has been confirmed by all succeeding experiments, there has been much difference with regard to the spot at which the heat is a maximum. The opinion of Herschel has however been fully confirmed by the recent observations of Mr. Seebeck.— *Edin. Jour. of Science*, i. 358.

When the solar rays traverse a biconvex lens, they are collected together in a focus, but the focus of the calorific rays is a short distance behind that of the luminous, showing that they are differently refracted.—*Berzelius.*

Beyond the confines of the spectrum on the other side, viz. a little beyond the violet ray, the thermometer is not affected ; but in this place it is remarkable that there are also invisible rays of a different kind which produce all the chemical effects of the rays of light, and with even greater energy. It is well known that if chloride of silver is exposed to the direct light of the sun, it is speedily changed from white to black. The rays separated by the prism possess this power of blackening chloride of silver in various degrees. The blue rays for example, effect a change in 15 seconds, which the red require 20 minutes to accomplish ; and, generally speaking, the power diminishes as we recede from the violet extremity. But entirely out of the spectrum the effect is still produced. Hence it is inferred that there are certain rays which excite neither heat nor light ; and which, from their peculiar agency, have been called *chemical* or *de-oxidizing rays.*

It appears, therefore, that a ray of light contains three distinct sets of rays, viz. the *illuminating*, the *heating*, and the *chemical* or *de-oxidizing*. It may also be added, that the more refrangible rays of light, seem to possess the property of rendering steel or iron magnetic : a property discovered by Dr. Morichini of Rome, and confirmed by the experiments of Mrs. Somerville, who succeeded in magnetizing a sewing needle by less than two hours exposure to the violet ray. (*Phil. Trans.* 1826.) This effect, however, has been much questioned, and is wholly rejected by Priess and Moser.—*Brewster's Edin. Jour. N. S.* ii. 225.

PHOSPHORESCENCE.

There are many bodies in nature which possess the property of giving out light without any sensible emission of heat ; and these are

commonly known by the name of *phosphori.* The leading divisions of these substances are:

1. *Solar phosphori ;* or those which require a previous exposure to solar or other light to become luminous. Such are Canton's, Baldwin's and the Bolognian phosphori, which will be described hereafter. To the same class belong several natural bodies which retain light and give it out unchanged. Thus, snow is a natural solar phosphorus.

2. *Phosphori from heat ;* or those which become luminous, by heat alone. Thus powdered fluate of lime becomes luminous, when thrown on an iron plate raised to a temperature rather above that of boiling water, and one of its varieties known to mineralogists by the name of *Chlorophane*, gives out abundantly an emerald green light, by the mere heat of the hand. The yolk of an egg, when dried, becomes luminous on being heated ; and so also do spermaceti, wax and tallow, during liquefaction. To exhibit the last mentioned fact, it is only necessary to place a lump of tallow on a coal, heated below ignition, making the experiment in a dark room.—*Brewster, on the phosphorescence of certain fluids, Edin. Jour. of Science*, iv. 178.

3. *Spontaneous phosphori ;* or those animal and vegetable substances which emit light spontaneously at common temperatures, without the necessity of previous exposure to light. This property is possessed in a remarkable degree by fish and some other marine animals ; and in these it makes its appearance before the commencement of putrefaction, and ceases when the latter is completely established. The luminosity of sea water is ascribed to the presence of animalculæ, which are naturally phosphorescent. Of vegetable matters which become luminous, the most remarkable is decayed wood.

The chemical effects of light are very evident in the case of a mixture of chlorine and hydrogen, which explodes and produces muriatic acid. Again, chlorine and carbonic oxide have scarcely any tendency to unite, even at high temperatures, when light is excluded; but exposed to the solar rays, they enter into chemical union. Chlorine also has but little action on water unless exposed to light. To the same class of the chemical effects of light, may be referred the decomposition of nitric acid, and the decomposition or change of colour of the salts of gold and silver.

The green colour of vegetables is also owing to the influence of solar light. [For additional facts on the subject of the chemical influence of light, see *Phil. Mag. and Ann.* vii. 462.]

Photometers or measurers of Light. For measuring the intensities of light from various sources, an instrument has been constructed which is called the *Photometer.* That of Mr. Leslie is founded on the principle, that light in proportion to its absorption, produces heat. The degree of heat produced, and consequently of light absorbed, is measured by the expansion of a confined portion of air. It is merely a very delicate and small differential thermometer, enclosed in a thin and pellucid glass tube. One of the balls, however, is rendered opake, either by tinging the glass or covering it with a pigment; and hence this ball, when the instrument is suddenly exposed to light, becoming warmer than the clear bulb, indicates the effect by the depression of the fluid. —*Leslie's Inquiry.*

Some objections to this instrument have been stated, for which the reader is referred to the Rev. Mr. Powell's Historical Sketch of Photo-

metry, in the *Ann. of Phil.* xxvii. 371, where will also be found a no-
tice of Rumford's Photometer, and of that proposed by Dr. Brewster;
—and to Mr Ritchie's paper on Leslie's Photometer, in the *Edin. Jour.
of Science*, ii. 321. 339. and iii. 104.   Brande's modification of Leslie's
Photometer, is described in his *Journal*, viii. 220.*

SOURCES OF LIGHT.

The sources of light are, *the Sun* and *Stars*, *Chemical action*, *Heat*
and *Percussion*. The first of these we have already noticed.

Chemical action. Whenever combustion forms a part of the pheno-
mena, light, as is well known, is given out; but light is also evolved
in other instances, where nothing like combustion takes place. Thus,
freshly prepared magnesia, added suddenly to highly concentrated sul-
phuric acid, exhibits a red light. When the vapour arising from a so-
lid, benzoic acid for instance, is condensed, light is evolved, and fused
boracic acid, when passing to a solid form, exhibits the same phenome-
non. So also some substances during the process of crystallization
give out scintillations of light, as sulphate of potassa and fluoride of
sodium.

Henry Rose states that if two or three drachms of the vitreous
arsenious acid be put into a matrass along with an ounce and a half of
muriatic acid and half an ounce of water, and the whole allowed to
boil for ten or fifteen minutes, and then cooled as slowly as possible ;
the crystallization is accompanied by a strong emission of light, the
formation of each little crystal being attended by a spark. If the ves-
sel is then agitated, a great number of crystals suddenly shoot up, and
an equal number of sparks occur at the same time. If a considerable
quantity of arsenious acid, such as an ounce and a half, or more, is
treated with a corresponding quantity of diluted muriatic acid, then,
on shaking the vessel, if the right moment is seized, the emission of
light from the shooting of the crystals is so powerful that a dark room
may be lighted up by it.—*Lond. & Edin. Phil. Mag.* vii. 534.

But, perhaps the most intense artificial light is that which is obtain-
ed by directing the flame of the oxy-hydrogen blow-pipe upon a small
spherule of lime, about a quarter of an inch in diameter. The lime
from chalk is best adapted to this purpose, as it is most easy to give it
the proper form. The light thus produced is so brilliant as scarcely to
be borne by the naked eye, and its use is therefore suggested for illu-
minating light houses. It acts also as solar light does on mixtures of
chlorine and hydrogen, and on chloride of silver.—*Drummond, Phil.
Trans.* 1826.   *Also Edin. New Phil. Jour.* i. 182.

Percussion. Light is also evolved by percussion and friction. Thus,
two pieces of common bonnet cane, rubbed strongly against each other
in the dark, emit a faint light. Two pieces of borax, quartz or sugar,
have the same property in a more eminent degree. Some of the gases
also, when highly compressed, give out light.

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* The indications of these photometers cannot be depended on when there
is much difference in the colour of the lights. In such cases the best method
of obtaining approximative results, is by observing the distance between each
light at which any given object, as a printed page, ceases to be distinctly visi-
ble. The illuminating power of the lights so compared is as the squares of
their distances.

Heat. When heat is applied to bodies, and continually increased, there is a certain temperature at which they become luminous; and the body is then said to be *red hot* or *incandescent.*

The temperature at which solids in general begin to shine in the dark, is between 600° and 700° F.; but they do not appear luminous in broad daylight, till they are heated to about 1000° F. The colour of incandescent bodies varies with the intensity of heat. The first degree of luminousness is an obscure red. As the heat augments, the redness becomes more and more vivid, till at last it acquires a full red glow. Should the temperature still continue to increase, the character of the glow changes, and by degrees becomes white, shining with increasing brilliancy as the intensity of the heat augments. Liquids and gases likewise become incandescent when strongly heated; but a very high temperature is required to render a gas luminous, more than is sufficient for heating a solid body even to whiteness. The different kinds of flame, as of the fire, candles and gas light, are instances of incandescent gaseous matter.

REFERENCES. *Biot's Traité Precis.* ii. *Brewster's Optics. Library of Useful Knowledge, Art. Double Refraction, and Polarization of Light. Thomson's Chemistry,* i. *Aikin's Chem. Dict Art. Phosphori. Lieut. Ingalls on the Luminousness of the Ocean, Trans. Alb. Institute,* i. *Osann on some New Bodies, which absorb light strongly, Edin. New Phil. Jour.* vi. 158. *Mr. Powell on Solar Light and Heat, Ann. of Phil.* xxiii. *and* xxiv. *Also, remarks by the same author on Light and Heat from Terrestrial Sources, Ann. of Phil.* xxiv. 181, xxv. 201, 359, 401, *and the same author's Report on Radiant Heat in the Transactions of the British Association for* 1832. *Herschel's Treatise on Light.*

CHAPTER IV.

ELECTRICITY.

The term ,Electricity, applied to the unknown cause of a peculiar kind of attraction, is derived from the Greek word *electron, amber,* because the electric property was first noticed in this substance.

In my remarks upon this subject, I shall briefly notice, 1st. the general or elementary facts of the science: 2d. the theory proposed to account for these facts: and 3d. the effects of accumulated electricity.

GENERAL FACTS OF ELECTRICITY.

The general facts of electricity may be conveniently reduced to the following, viz: EXCITATION—ATTRACTION—REPULSION—DISTRIBUTION—TRANSFERANCE and INDUCTION. — *Library of Useful Knowledge, Art. Electricity.*

All these facts can be shown with the simple apparatus of a clean and dry glass tube, a dry silk handkerchief, and a few pith balls, suspended by silken threads. But they are much more strikingly exhi-

bited if we employ an *electrical machine*, an instrument which consists essentially of a circular plate of glass, or a glass cylinder, fixed upon an axle, and pressed by a cushion or *rubber*, which is generally besmeared with a soft compound, or an amalgam of mercury and tin with grease. At a short distance, is placed a metallic cylinder, supported by glass feet, called the *prime conductor*, which at the end next the glass, has commonly a few projected teeth made of pointed wire.

If now the rubber is connected by a small chain or otherwise, with the table or floor, and the glass cylinder or plate made to revolve upon its axle, a crackling noise is heard, accompanied with a luminous appearance, and on bringing the knuckle or a rounded metallic knob, near the prime conductor, a spark issues, accompanied with a snap or slight report, and with a pricking sensation when the knuckle is presented. The glass is in this case said to be *excited*, and the substances thus susceptible of excitation are termed *Electrics*, in contradistinction to such as are not excited by a similar process, and which are termed *Non-electrics*. This distinction, however, is not founded in nature, for electricity may be excited in all solid bodies by friction, though for this purpose the friction is to be applied in different ways.

Attraction and Repulsion. If, while the prime conductor is *charged* with electricity, a light body, as a pith ball, suspended by a silken thread, be brought near it, it is *attracted* by the conductor and adheres to it for a certain time ; after which it recedes, or is *repelled* from it. This change, however, does not take place in all bodies with equal rapidity ; some require a considerable time before they begin to recede ; others, and especially metallic bodies, are repelled the instant after contact. The phenomena of attraction and repulsion can also be strikingly exhibited by several amusing experiments ; as the electrical bells, the electrical dance, &c.

It appears therefore that when bodies are electrified by contact with excited glass,they are repelled by it. The same thing also takes place when they are electrified by excited resins. But when a body electrified by glass is brought near a body electrified by the resins, instead of repelling each other, they are now attracted. From these facts the following general laws have been deduced, viz : *Bodies similarly electrified, repel each other ; bodies differently electrified, attract each other.*

It should be remarked also, that the production or excitation of one kind of electricity is always attended by the excitation of the other. Thus when glass is rubbed by silk or cloth, they assume opposite electrical states. This can be shown most strikingly by insulating the rubber of an ordinary machine.

Distribution and Transference. If a pith ball or metallic globe, suspended by silk, after having been in contact with a charged conductor, be removed, and the ball be brought near to another ball, suspended in a similar manner, they will approach each other and then again recede. This second ball, when brought near a third, will exhibit the same phenomena, although in a less striking manner, as the amount of electricity becomes gradually diminished by these successive operations. It is evident, therefore, that the electricity communicated to the first ball may be communicated to the second, and that from the second to the third, &c. in the same manner that heat is transferred from one body to another.

If, however, we bring in contact with a ball thus electrified, the hand

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or a metallic body, we observe, in some instances, a *spark*, and it loses the property of attracting another unelectrified ball, in consequence of the electricity having passed into the body. But if a tube of glass be substituted for the hand or the metallic rod, the body touched retains the whole of its electricity. We therefore infer that some bodies, as glass, are incapable of conducting electricity, while others, such as the metals and the human body, readily convey that influence. Hence the division of bodies into *conductors* and *non-conductors ;*—the latter being those which are electrics, and the former, non-electrics. The two qualites, of a capability of excitation and a power of conducting electricity, appear to be incompatible with each other ; for the one is always found to diminish in proportion as the other increases. The permanence of electricity in metallic bodies, which are suspended in the air by silk threads, shows that the air, as well as silk, is a non-conductor. Bodies which, in this way, are surrounded on all sides by non-conductors, are said to be *insulated*. The air, however, when it contains much moisture, becomes a conductor ;—and the conducting powers of most bodies are influenced by changes of form and temperature. The metals are the most perfect conductors ; the resins, amber and gumlac, the most perfect non-conductors.

The phenomena of the transference of electricity are modified by the form of bodies. Hence the different effects which are observed when conductors in the form of balls, or pointed ones, are charged with the fluid. In the former case the electricity is equally diffused over the surface of the ball, and it has a low intensity ; in the latter, the intensity is greatly increased at the extremities, and this is accompanied with a powerful tendency in the fluid to escape.*

Induction. It has been shown that when an excited electric is brought near to an insulated ball, the latter is attracted. This arises from the fact that the natural state of the body has been disturbed, and an electricity of an opposite kind has, as it is said, been *induced,* in that part of the ball nearest to the electric ; whereas that part of the ball which is most distant has the same electrical state as the electric.

Thus when an unexcited conductor AB, supported on an insulated

* As the terms *quantity* and *intensity* or *tension* are often employed in treating of electricity and galvanism, it may be proper to explain them more particularly. The former implies the actual quantity of electric power in any body ; whereas *intensity* or *tension,* signifies the state of electricity indicated by the electrometer, and its power of flying off from surfaces and passing through a certain stratum of air or other ill conducting medium. Tension appears to depend upon the quantity of electricity accumulated on a given space ; and hence the intensity of those substances is the greatest, which have the greatest excess or deficiency of electricity in proportion to their surface. Suppose a charged Leyden jar to give a spark when discharged, of one inch in length, another uncharged jar, communicating with the former, would upon the same quantity of electricity being thrown in, reduce the length of the spark to half an inch : thus the *quantity* of electricity remaining the same, its *intensity* is diminished by one-half, by its distribution over a larger surface.

This accounts for the freedom with which electricity is given off by pointed conductors. For through the quantity of electricity accumulated on a sharp point, may be very small, it is still large when compared with the surface. The electric tension of the point is therefore very great, and hence, if positive, it gives off electricity to surrounding bodies, and if negative, receives it from them, with extreme velocity.

glass rod is brought near a con-
ductor C charged with positive elec-
tricity and similarly insulated ; the
end A becomes negatively electri-
fied while B has the same electric
state as the conductor C. The elec-
tricity thus developed by the conti-
guity of an electrified body is said
to be excited by *induction ;* and at-
traction is in all cases the result of this principle. But when the two
conductors come into contact they soon become of the same electric
condition and bodies attached to them repel each other.
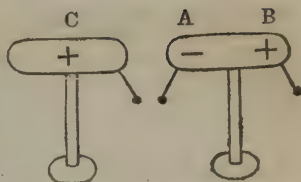
This principle can be more satisfactorily shown by the *Leyden Jar*,
the inner side of which, by communication with the charged conduc-
tor of a machine, is rendered positive, whereas the outer side is ren-
dered negative by induction. When these two sides are brought into
contact, by means of a *discharger*, the restoration of the equilibrium
of electricity is attended with a snap or report. These explanations,
however, will be better understood, from the following brief exposition
of the

THEORY OF ELECTRICITY.

The phenomena of electricity are ascribed by some philosophers to
the agency of one fluid, and by others to that of two distinct fluids.
The latter opinion was originally proposed by Dufay, and is almost ex-
clusively adopted in France; the former was proposed by Franklin,
and is generally received in England and America. It is somewhat
singular that most of the phenomena can be equally well explained
upon either hypothesis, and as has been remarked, " the selection de-
pends more upon the taste than the judgment of the inquirer." The
former of these theories is adopted in the present work.

Electricity, according to the Franklinian hypothesis, is a subtle,
highly elastic and imponderable fluid, which pervades all material
bodies, and is capable of moving through the pores or substances of
various kinds of matter. It moves through bodies with various degrees
of facility, through some, as the conductors or non-electrics, passing
freely ; through others, as the electrics or non-conductors, with great
difficulty. The particles of this fluid repel one another, and attract
the particles of all other matter, with a force varying inversely as the
square of the distance.

Bodies, on this hypothesis, are supposed to be in their natural state,
with regard to electricity, when, the repulsion of the particles of the
fluid is exactly balanced by the attraction of the matter for the same
particles. In this state bodies are supposed to be saturated with the
electric fluid. When they contain a quantity greater than this, they
are said to be *positively electrified*, or over charged with the electric fluid ;
when the quantity is less than this, the body is said to be *negatively
electrified*, or under charged. These different states are sometimes re-
presented by the terms *plus* and *minus*.

According to this theory, when a body is positively electrified, or
has more than its natural quantity of electricity, the surplus, in con-
sequence of the mutual repulsion of its particles, has a tendency to
escape, and this continues until the body is reduced to its natural state.
Again, when a body is negatively electrified, or contains less than its
natural quantity of electricity, it has a tendency to attract the fluid

from all sides, until the neutral state is again restored. When a glass globe or tube is excited by silk, the electricity leaves the silk and is accumulated on the glass; the silk, therefore, becomes negative and the glass positive.

There was however, one defect in the original Franklinian theory, which was detected by Æpinus and confirmed by Cavendish, and which rendered it necessary to add another condition to it. The defect was, that while the repulsion which is observed between two positively electrified bodies was easily accounted for, the repulsion between bodies negatively electrified was left without explanation. By the theory, this could not be referred to the repulsion of the particles of electric fluid, for they were supposed to contain less than their natural amount. It was necessary, therefore, to annex the additional condition, *that particles of matter uncombined with electricity, exert a repulsive action upon one another*. Without this, as can easily be shown, we are not only unable to account for the repulsion existing between bodies negatively electrified, but also for the want of action between two neutral bodies. The repulsion of two negatively electrified bodies, therefore can only be considered as the result of the repulsion of the particles of matter.

It will now be seen that the theory, as thus developed, satisfactorily explains the elementary facts which have been set forth, and will bear application to all the phenomena which electricity presents. Thus, by the operation of friction, the natural state of bodies is disturbed; and, as the result of this, there is an accumulation of electricity on one side and a diminution on the other, and the bodies are excited. The phenomena of attraction and repulsion, of distribution and transference, can also be readily accounted for. And the law of induction, moreover, is a consequence of the theory. For when a body overcharged with electricity is presented to a neutral body, the repulsive force existing among the particles of electricity in the former has a tendency to drive the electricity from the nearest part of the neutral body, if a conductor, to that which is the most remote. The nearest end of the body, therefore, becomes negatively electrified, while the remote end becomes positively electrified. Now if, instead of a positively electrified body, we bring a negatively electrified one near a neutral body, its attraction for the fluid in the second body will cause an accumulation in the nearest end, and of course a deficiency in the remote end.

Electroscopes and Electrometers. For the purpose of ascertaining when a body is electrified, and also the *intensity* or degree to which it is excited, instruments have been constructed which are called *Electroscopes* and *Electrometers*. Although the term electrometer is often indiscriminately applied to both those instruments, the latter denotes the intensity of electricity, the former merely indicates excitement and the electrical state by which it is produced.

One of the simplest electroscopes is that of Hauy, which consists of a light metallic needle, terminated at each end by a light pith ball, which is covered with gold leaf, and supported horizontally by a cap at its centre, on a fine point. The attractive or repulsive power of any electrified body, presented to one of the balls, will be indicated by the movements of the needle. In some cases, however, it is more convenient to employ a pair of similar balls, suspended from a brass ball, fixed to the end of a glass handle, by very fine silver wires, or by hem-

pen threads, previously steeped in a solution of salt and afterwards dried.

Electrometers are constructed upon the principle, that the more highly an insulated conductor is charged with electricity, the more powerful is the repulsion which it communicates to bodies which are brought near it. Henley's *Quadrant Electrometer*, is in common use. Bennett's *Gold Leaf Electrometer*, is not only a more delicate instrument, but we are enabled by it to discriminate between positive and negative electricity. It consists essentially of a cylindrical glass bottle, with its apertures closed by a brass plate, from the centre of which two slips of gold leaf are suspended. The brass plate, with its slips of gold leaf, are thus insulated, and the latter prevented from being moved by currents of air, by the glass with which they are surrounded. The approach of any electrified body, even though feebly excited, to the brass plate, is immediately detected by the divergence of the leaves. If the divergence be increased by the approach of flint glass excited by silk, the electricity is said to be positive; if the divergence be diminished, they are said to be negatively electrified.—This instrument is, strictly speaking, an electroscope.

Balance Electrometer. This instrument contrived by Mr. Harris, of Plymouth, [Eng.] consists of a brass beam I, supported by a conductor CD, on a wooden frame AA; E is a scale for holding weights and F its support; G and H are gilt cones made of light wood, G being suspended by a silver wire from I, and H insulated by the glass support KL. The instrument is prepared for use by placing G and E, in exact equipoise. The cone G is suspended so that its base shall be opposite and parallel to the base of the cone H, as may be done by means of three adjusting screws in the frame AA and H is raised by help of a graduated brass slide N, until the bases of the cones are just in contact. The cone H is then depressed to any desired distance which may be varied at will during an experiment. The same cone is connected with the inner coating of a Leyden jar, the outer coating of which communicates with the frame AA, and along DCI with the cone G; these cones may thus be made parts of a charged Leyden jar, and be oppositely excited, as indicated by the signs + and — . The attractive forces between their bases tends to draw down the cone G into contact with H discharging the jar; but before it can do so, it has to overcome the weight which may be in the scale E. By this ingenious contrivance any number of attractive forces are estimated by a common standard, namely, the number of grains which each is able to raise.—*Turner.*
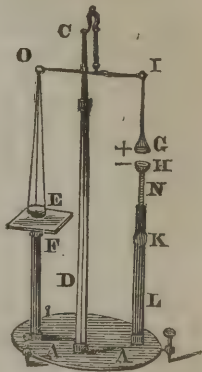
Mr. Harris has also invented another instrument which he calls the *Unit Jar*, the principal use of which is in charging other Leyden jars with known proportions of electricity.

The most perfect electrometer for measuring small quantities of
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electricity, is the apparatus described by Coulomb, and to which he has given the name of the *Torsion Balance*, for a description of which we must refer to elementary works on Natural Philosophy, or to the Library of Useful Knowledge, art. Electricity.

EFFECTS OF ELECTRICITY.

Independently of electrical attraction and repulsion, it does not appear that the simple accumulation of electricity in any quantity in bodies, as long as it remains quiescent, produces the least sensible change in their properties. A person standing on an insulating stool, may be charged with any quantity of electricity from a machine, without being perceptibly affected, until the equilibrium of the fluid is disturbed, by drawing sparks from his body or from the prime conductor with which he may be in communication. It is the passage of electricity therefore, which produces the effects now to be noticed.

When this passage is uninterrupted, as is the case in rods of metal, no perceptible change in the mechanical properties of the body is produced. But very considerable effects are produced, either if the body is so small as not to admit the whole quantity of electricity to pass with perfect freedom; or if the body, though large, is deficient in conducting power.

The effects of electricity may be conveniently arranged under the following heads, viz.

1. *The mechanical effects*, which can be illustrated by various experiments; as by passing a charge of electricity through a capillary tube containing mercury, oil, water, alcohol, or ether; or by passing it through a small plate of glass, a piece of pasteboard, a card, or through the leaves of a book.

2. *The evolution of heat.* The ignition and fusion of the metals by the electric discharge, are phenomena which have been long observed. Thus a very fine wire may be fused by a powerful Leyden battery, or if the wire be sufficiently fine, by a single jar; and so also alcohol, ether and spirits of turpentine may be inflamed by the spark from the prime conductor, as well as by the discharge from the jar. Gun-powder may be fired by partly interrupting the electric circuit, as by causing the wire or chain to pass through a vessel of water.

Light as well as heat are emitted during the electrical discharge, at every point where the circuit is either interrupted or is occupied by bodies of inferior conducting powers. Thus a moderate charge from a Leyden jar will produce a bright spark when made to pass through water, and the spark is still more luminous in oil, alcohol, or ether, which are worse conductors than water; on the contrary, in fluids of greater conducting power, there is greater difficulty of eliciting electric light.

3. *The chemical effects.* These will be more strikingly shown when treating of Galvanism; but they can also be exhibited by powerful electrical machines. Thus when a strong charge is sent through water, it is decomposed and resolved into oxygen and hydrogen, which immediately assume a gaseous form. So also oxides of tin and mercury may be reduced to the metallic state.

If a narrow glass tube containing chloride of silver be subjected to a series of electric sparks from an ordinary machine for five or ten min-

utes, by means of two metallic wires fixed into the end of the tube, the silver will be reduced ; and if potassa be substituted for the chloride of silver, the potassium will be seen to take fire as it is produced.

4. *Effects upon animals.* When one hand communicates with the negative side of a charged jar, and the other hand is brought into contact with the positive side, a shock is observed more or less powerful according to the amount of electricity which has been accumulated. This shock is felt, especially at the joints, for the reason probably that the fluid meets with greater resistance in passing from one bone to another. When a shock is passed through the muscles, a convulsive motion is produced, even in those cases where the nerves of a limb are completely paralyzed. But upon the nervous system, these effects are still more striking.

Atmospheric Electricity.

The atmosphere is generally in an electrical state. This fact can be shown by employing a metallic rod elevated to some height above the ground, and communicating at its lower end with an electroscope. Or, if we wish to collect electricity from the higher regions of the air, a kite may be raised, in the string of which a slender metallic wire should be interwoven, so as to conduct the electricity. The electroscope attached to this, will usually show the prevalence of the positive electricity, which increases as you ascend. This atmospheric electricity, however, varies in quantity at different seasons of the year, and at different times of the day ; and alternates from the positive to the negative. Upon the approach of thunder storms, these alternations succeed each other with great rapidity : strong sparks are given out by the conductor, and it becomes dangerous to prosecute the experiments with it in its uninsulated state.*

Although the analogy between the electric spark and lightning, had been a subject of remark among the earliest experimenters upon electricity, it remained for Dr. Franklin to prove it directly. He did this by the celebrated experiment of raising a kite during a storm, when he succeeded in obtaining sparks from a key attached to the lower end of the hempen string of the kite. This grand discovery excited the attention of philosophers in every part of the world, and the experiment was every where repeated. It was, however, in many instances, attended with risk, and proved fatal to Professor Richman, of St. Petersburgh, in 1753.

The most important practical application of the theory of electricity, is the protection of houses, ships, &c. from the effects of lightning. This is affected by means of a metallic conductor, which is called a *Lightning-rod ;* being a rod of iron or copper, about half an inch in diameter, the extremity of which projects some distance above the building, and is pointed with silver, platinum, or gold, the more com-

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* Water may be readily decomposed by atmospheric electricity in the manner proposed by M. Bonijol. The electricity is gathered by means of a very fine point fixed at the extremity of an insulated rod ; the latter is connected with the apparatus, in which the water is to be decomposed, by a metallic wire, of which the diameter does not exceed 1-50th of an inch. In this way the decomposition of the water proceeds in a continuous and rapid manner, notwithstanding the electricity of the atmosphere is not very strong. Stormy weather is quite sufficient for the purpose.—*Bib. Univ.*

pletely to preserve it from corrosion. No interruption should exist in the rod, and the lower end should be carried into the earth until it reaches water, or at least a moist stratum.

REFERENCES. *Franklin's Works. Library of Useful Knowledge, art. Electricity. Priestley's History of Electricity. Cavallo's Philosophy. Biot's Traité de Physique, or Cambridge Course of Physics. Gay Lussac's instructions respecting Paratonnerres, or Conductors of Lightning, Ann. of Phil.* xxiv. 427. *Pouillet's Elémens de Physique,* ii. *Cuthbertson's Practical Electricity and Galvanism.*

GALVANISM.

The science of Galvanism owes its name and origin to the experiments made by Galvani, Professor of Anatomy at Bologna, in Italy, in the year 1790. Being engaged in some researches on animal irritability, he observed that when a piece of zinc was placed in contact with the nerve of a frog, and a piece of silver or copper with the muscle, the animal was violently convulsed. In this fact he conceived that he had found a strong confirmation of a theory which he had adopted, that the nervous fluid was somewhat analogous to electricity, and these convulsions were consequently ascribed by him to a discharge of this nervous or electrical energy from the muscles in consequence of the conducting power of the metals. And to this he gave the name of *Animal Electricity.*

The fallacy of the notions of Galvani was first pointed out by the celebrated Volta, of Pavia, who in repeating the experiments, soon established the fact that electricity is excited by the contact of the metals, and that the convulsions are owing to the current passing through the conducting muscle and nerve.* And as it is to him we are indebted for the first true explanation of this curious fact, so did he first contrive an apparatus for exciting electricity in this manner.

The instrument constructed by Volta for this purpose was called the *Pile;* a description of which was first published in the Philosophical Transactions, for 1800. It consists of any number of pairs of zinc and copper, or zinc and silver, plates ZC, each pair being separated from the adjoining ones by pieces of cloth K, nearly of the same size as the plates, and moistened in a saturated solution of salt. The relative position of the metals in each pair must be the same in the whole series; that is, if the copper is placed below the zinc in the first combination, the same order must be preserved in all the others. The pile is contained in a proper frame, formed of glass pillars, fixed into a piece of thick wood, which both supports and insulates it.

This form of the galvanic series, soon gave place to the more convenient one of the *Trough*, or battery, invented by Mr. Cruickshank. This consists of

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* This fact may be illustrated by the following simple experiment. Place a piece of silver *upon* the tongue, and a piece of zinc *under* it; upon bringing their ends into contact we immediately perceive a saline taste and a peculiar sensation resembling a slight electric shock. Sometimes, also, when the surface of the metals is extensive, a flash of light appears to pass before the eyes; an effect which may be more certainly produced by placing one metal between the upper lip and the gums, and bringing their ends together as before.

a trough of baked wood AB, in which are placed at equal distances, any number of zinc and copper plates, previously soldered together, and so arranged that the same metal shall always be on the same side. Each pair is fixed in a groove cut in the sides and bottom of the box, the points of junction being made water-tight by cement.   The apparatus thus constructed is always ready for use, and is brought into action by filling the cells left between the pairs of plates with some convenient solution, which serves the same purpose as the moistened cloth in the pile of Volta. If then the zinc surfaces face towards Z and the copper towards C the pole or wire proceeding from C will be positive while that from Z will be negative.   But if these surfaces face in contrary directions the poles will be reversed.
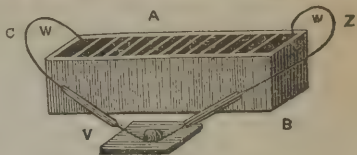
Several modifications in the construction of the battery were afterwards proposed. One of these was suggested by the *Couronne des Tasses* of Volta ; in which the trough made either of baked wood or glazed earthen, is divided into partitions by the same material.   A more important improvement was suggested by Dr. Wollaston, who recommends that each cell should contain one zinc and two copper plates, so that both surfaces of the first metal are opposed to one of the second. By this arrangement the plates of copper communicate with each other, and the zinc between them with the copper of the adjoining cell. An increase of one half the power is obtained by this method.

After an extensive series of experiments, Mr. Faraday gives the preference to the battery invented by Prof. Hare of Philadelphia, and described by him under the name of the *Galvanic Deflagrator*. In this instrument, the copper plates, which pass round both surfaces of the zinc plates, are separated by thin veneers of wood, and the acid is poured on to, or off, the plates by a quarter revolution of an axis, to which both the trough containing the plates, and another trough to collect and hold the liquid, are fixed.   Mr. Faraday adopted the following mode in con-

Fig. 1.

Fig. 2.   Fig. 3.

structing his battery. The zinc plates were cut from rolled metal and when soldered to the copper plates had the form delineated in fig. 1. These were then bent over a gauge into the form fig. 2, and when pack-

ed in the wooden box constructed to receive them were arranged as in fig. 3, little plugs of cork being used to keep the zinc plates from touching the copper plates, a single or double thickness of cartridge paper being interposed between the contiguous surfaces of copper to prevent them from coming in contact.—*Phil. Trans. for* 1835, *Part* II.

The size and number of plates are subject to every variety. The largest battery ever made, is said to be the one of Mr. Children, the plates of which are six feet long and two feet eight inches broad. [See *Ann. of Phil.* vii. 11.] The great battery of the Royal Institution, with which Sir Humphry Davy established the true nature of the fixed alkalies and alkaline earths, is composed of 2000 pairs of plates, each plate having 32 square inches of surface. These form a striking contrast to the elementary battery of Dr. Wollaston, consisting of a single pair of plates, of very small dimensions, with which he succeeded in fusing and igniting a fine platina wire.—[*Ann. of Phil.* vi. 209.] All the effects of the battery may be exhibited by forty or fifty pairs of plates three inches square, arranged in the manner described by Mr. Faraday.

The fluid generally used for rendering these batteries energetic, is one of the stronger acids, diluted with 20 or 30 times its weight of water. Mr. Children recommends a mixture of three parts of fuming nitrous acid, and one of sulphuric, diluted with 30 parts of water. According to Gay Lussac and Thenard, dilute nitric acid is the best where we wish to produce instantly the highest energy of the battery —while muriatic acid should be employed when the object is to obtain a prolonged action. For ordinary experiments Mr. Faraday prefers the following proportions viz. 200 parts of water, $4\frac{1}{2}$ of sulphuric acid and 4 of nitric acid. Whichever of these proportions we employ, it is of great importance that all the cells of the voltaic battery be excited with a liquid of the same strength.

The *Electric Column* may be classed among galvanic arrangements. It was originally contrived by M. De Luc, who formed it of disks of Dutch gilt paper, alternated with similar disks of laminated zinc. These were piled on each other in a dry state, (or at least in a state of dryness at ordinary temperatures, for paper cannot be made or preserved absolutely dry, except at a heat nearly sufficient to scorch it.) This instrument, instead of being soon exhausted, like the pile with humid substances, was found to continue active for some years. A similar pile may be formed, by laying a mixture of very finely powdered zinc with common glue and a little sugar, by means of a brush, on the back of Dutch gilt paper, and when dry, cutting it into disks, which are to be piled on each other.—[*Phil. Mag.* xlvii. 265.] Zamboni, of Verona, has constructed a pile of slips of silver paper, on the unsilvered side of which is spread a layer of black oxide of manganese and honey. These papers are piled on each other, to the number of 2000; then covered externally with a coating of shell-lac, and enclosed in a hollow brass cylinder. Two of these piles are placed at the distance of four or five inches from each other; and between them is suspended, on a pivot, a light metallic needle, which is attracted alternately to the one pile and the other, so that it moves between them like a pendulum. This instrument has been applied to the measurement of time, by causing it to give motion to the pendulum of a clock.—*Phil. Mag.* xiv. 261. *Henry*,i. 188.

The more striking effects of the voltaic battery may be reduced to four general heads,

I. ITS ELECTRICAL PHENOMENA.

II. ITS CHEMICAL AGENCY.

III. ITS POWER OF IGNITING THE METALS.

IV. ITS ACTION ON THE MAGNET.

I. *Electrical Phenomena.* Galvanism, even when excited by a single galvanic circle only, (such as a piece of zinc, a similar one of copper, and a piece of cloth moistened with a solution of muriate of ammonia,) distinctly affects the gold leaf of Bennet's electrometer. If the zinc end be uppermost, and be connected directly with the instrument, the electricity indicated is positive ; if the pin of the electrometer, touch the copper, the electricity is negative. A pile consisting of sixty combinations produces the effect still more remarkably. [For cautions necessary to the success of this experiment, see *Singer,* 317.]

The voltaic apparatus is capable of communicating a charge to a Leyden jar, or even to a battery. If the zinc end of a pile be made to communicate for a moment, with the inside of a jar, it is charged positively. If the circumstances be reversed, the jar is charged negatively.—*Cuthbertson's Practical Electricity and Galvanism,* 261.

The sensation produced by the galvanic shock is extremely similar to that which is excited by the discharge of a Leyden jar. Both influences, also, are propagated through a number of persons, without any perceptible interval of time.

The galvanic fluid passes through the air, and certain other nonconductors, in the form of sparks, accompanied with a snap or report ; and, like the electrical fluid, it may be made to inflame gun-powder, phosphorus, and mixtures of hydrogen and oxygen gases. It has been found, also, by Mr. Children, that in the voltaic apparatus, there is what is called in electricity, *a striking distance.* With a power of 1250 pairs of four inch plates, he found this distance to be one 50th of an inch, the thickness of a plate of air, through which the galvanic discharge is able to pass in the form of a spark. By increasing the number of plates, the striking distance will be greater, and the reverse when it is diminished. It is also increased by rarifying the air, through which the spark is transmitted.—*See Henry's Chemistry, on the mutual relations of Electricity and Galvanism,* i. 189.

For the purpose of exhibiting the effects just mentioned, a number of plates is necessary, without reference to the size. Acid solutions are to be preferred when shocks or sparks are required ; water is preferable for effecting the electrometer or Leyden jar.

Thus it appears that while the current of electricity from an electrical machine has a decomposing power, the voltaic apparatus produces electrical effects no less striking. There is, therefore, the most satisfactory evidence that both sets of phenomena are to be ascribed to the same agent: Mr. Faraday has also recently shown that a magnetic needle may be deflected with an electric current from the machine, and his researches have led to a remarkable contrast between the quantity of electricity concerned in the production of voltaic and ordinary electrical phenomena. He states that the quantity of electric fluid employed in decomposing a single grain of water is equal to that of a very powerful flash of lightning.

II. *Chemical effects of the battery.* The chemical effects of the battery first noticed, was the decomposition of water, which, as we shall hereafter see, is a compound of oxygen and hydrogen.

When two gold or platinum wires are connected with the opposite poles of a battery, and their free ends plunged into the same cup of water, but without touching each other, oxygen gas is disengaged at the positive wire, and hydrogen gas at the negative. These gases may be collected in separate tubes, or in a single bent tube, and subjected to experiment. [See a very simple apparatus for collecting the gases evolved from liquids submitted to galvanic action, by the Rev. Mr. Robertson, in *Edin. New Phil. Jour.* iii. 44.] If, however, we employ wires of copper, silver, or any other oxidable metal, the oxygen no longer appears in the form of gas, but unites with the wire, and oxidates it.

If, instead of water, we subject to the action of the poles of the battery, acids or saline solutions, they are, in like manner decomposed; one of their elements appearing at one pole and the other at the other. There is an exact uniformity in the circumstances attending these decompositions. Thus, in decomposing water or other compounds, the same kind of body is always disengaged at the same pole of the battery. The metals, inflammable substances in general, the alkalies, earths, and the oxides of the common metals, are found at the negative pole; while oxygen, chlorine, and the acids pass over to the positive end.

It was also asserted by Davy that if the conducting wires are plunged into separate vessels of water and made to communicate with each other by moist fibres of cotton or amianthus, the two gases are disengaged in the usual order. And if one vessel containing a neutral salt (sulphate of soda, for example,) communicates with the negative pole, and another containing distilled water with the positive, and the two cups be united by moistened amianthus, the acid of the salt passes over to the water, and the salt becomes distinctly alkaline. What was still more remarkable the same results were said to be observed when a cup of ammonia intervened between those of distilled water and the saline solution; the inference from which singular occurrence was, that galvanic action not only separates the elements of compound bodies, but suspends the operation of affinity so entirely as to enable an acid to pass through an alkaline solution, or an alkali through water containing a free acid without combination taking place between them.—*Phil. Trans. for* 1807.

Mr. Faraday, however, in his recent researches on electricity seems to have fully established the fact that, in order that the elements of decomposed water should appear at the opposite poles or electrodes* there must be water between the electrodes; and for the similar separation of sulphuric acid and soda, there must be a line of particles of sulphate of soda extending from one electrode to the other. Thus, if a solution of sulphate of magnesia be covered with pure water, care being taken to avoid all admixture of particles, and the positive metallic termination or pole touch the magnesian solution only, while the negative pole is in contact with the water only, a deposit of magnesia occurs just where the pure water and the magnesian solution meet, and none reaches the negative pole. In Davy's experiment, where sulphuric acid and soda appeared to quit each other, and pass over separately into a vessel of pure water, there was certainly by capillary attraction an actual trans-

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* Mr. Faraday contends that what are commonly called the *poles* of the voltaic battery have no attractive or repulsive energy, and act simply as a path or door to the current; he hence calls them *electrodes*, from the Greek *electron*, and *odos*, a way.

ter of the salt before decomposition occurred.—*Phil. Trans. for* 1833 *and* 1834 ; *Turner's Chemistry.*

It has been shown, in the chapter upon electricity, that bodies which are similarly electrified repel each other, while those which are dissimilarly electrified attract each other. Now the invariable tendency of oxygen and the acids to the positive pole of the battery, and of hydrogen and the alkalies to the negative, can only be explained upon the principle that the former are negatively, and the latter positively electrified at the moment of their separation from each other. This forms the basis of the hypothesis advanced by Davy, which has received the appellation of the *Electro-Chemical Theory,* and has been adopted by several philosophers, especially by Berzelius.

According to Volta when two metals are brought into contact, they are, on being separated, in opposite electrical states. Thus, when an insulated plate of zinc is brought into contact with one of silver or copper, the former is found to be in a *positive* state, and the latter *negative.* Sir H. Davy also ascertained that a similar effect is produced by the contact of other bodies. A dry alkali or an alkaline earth, for example, is excited positively by contact with a metal; dry acids after having touched a metal are negative, and the contact of acids and alkalies, in their dry state, render the former negative and the latter positive. He further observed that *electrical* effects are exhibited by the same bodies, when acting as *masses,* which produce *chemical* phenomena when acting by their particles, or atoms. It is, therefore, by no means improbable, that the primary cause of both these phenomena may be the same, and that the same arrangements of matter which render bodies attractive of each other electrically, may likewise render their particles attractive, and enable them to combine, when they have full freedom of motion.

According to the above view, all substances which have a chemical affinity for each other, are in different states of electricity, and the degree of affinity is proportional to the intensity of these opposite states. When such a compound body is placed in contact with the poles of a volatic battery, the positive pole attracts the constituent which is negative, and repels the positive. The negative acts in the opposite way, attracting the positive constituent and repelling the negative. Thus, when water is subjected to the action of the battery, its oxygen invariably appears at the positive pole, and its hydrogen at the negative. Hence hydrogen and all other substances which like it are attracted by the negative pole, are classed together as *electro-positive bodies;* and oxygen and other substances which are attracted by the positive pole are called *electro-negative bodies.*

In following out these ideas, Davy conceived that no compound could resist decomposition, if subjected to the action of a battery of sufficient power. He accordingly exposed to galvanic action substances, which, although they had been thought to be compound, had baffled all attempts to analyze them. The result was successful. Potash was proved to consist of a metallic basis in combination with oxygen, and continuing his investigations, he soon decomposed the other fixed alkalies and alkaline earths, and rendered it almost certain that the earths proper were similarly constituted.

Such is an outline of the views entertained by Davy in regard to the chemical and electrical relations of bodies, and which have been adopted by a great majority of chemists; recent investigations, however, and especially those of Mr. Faraday, would seem to have rendered

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their correctness more than doubtful. But while this theory has been pronounced untenable by high authority, it is also admitted that there is no other which accounts for all the phenomena.

III. *The igniting effects of the battery.* The ignition of the metals seems to depend upon the difficulty with which electricity passes along them. But as they are perfect conductors, this can only take place when the quantity to be transmitted is out of proportion to the extent of surface along which it has to pass. For this purpose, therefore, it is important to excite as large a quantity of electricity in a given time as possible; and hence a few large plates answer a better purpose than a number of small ones. A strong acid solution should also be used, as an energetic action is more important than its permanence.

IV. *The action on the magnet.* This interesting subject will be noticed in connection with the general view of the laws of magnetism, in the next chapter.

THEORIES OF GALVANISM.

There are three leading theories which have been constructed to account for the phenomena of the galvanic pile, and of all similar arrangements. The first originated with Volta, who maintained, that the electricity was set in motion and kept up solely by the contact of the metals. But as no very sensible effects are produced, unless the substances employed have a chemical action on each other, Dr. Wollaston was led to conclude, that the process commences with the oxidation of the zinc, and that the oxidation is the primary cause of the developement of electricity. The theory of Davy is intermediate between the two just mentioned. He supposed that the contact of the metals disturbs the electric equilibrium, and that the electric action is afterwards kept up by the action of the solution upon the zinc. The researches of Mr. Faraday tend fully to establish the theory of Dr. Wollaston, to the entire exclusion of that of Volta. For farther details in regard to these theories the reader is referred to *Bostock's Remarks on the Hypotheses of Galvanism, in Ann. of Phil.* iii. 32, 85 ; *Sir H. Davy's chapter on Electrical Attraction and Repulsion, in his Chem. Phil. Gay Lussac and Thenard's Researches ; and to Faraday's Experimental Researches in Electricity, Phil. Trans. for* 1833 *and* 1834.

REFERENCES. *Cuthbertson's Practical Electricity and Galvanism. Singer on Electricity and Galvanism. Several papers by Volta, Singer, De Luc, and Henry, in Nicholson's Journal. Library of Useful Knowledge, Art. Galvanism, by Dr. Roget. Davy on the Chemical Agencies of Electricity, Phil. Trans.* 1807 *and* 1826, *and also Phil. Mag. and Ann.* i. *Oersted on the Identity of Chemical and Electrical Forces, Ann. of Phil.* xiii. 369, 456. xiv. 47. *Thomson's Outline of the Sciences of Heat and Electricity. The first eight volumes of Silliman's Journal contain sundry papers by Professors Hare and Silliman, upon Calorimotors, Deflagrators, &c.*

CHAPTER V.

MAGNETISM.

Though the consideration of Magnetism belongs strictly to the department of natural philosophy, I shall advert briefly to its more prominent laws, as by this means the student will be better prepared to understand the facts of Electro-Magnetism.

Most of the fragments of iron ore in which a degree of oxidation has taken place, are found to possess, when taken from the earth, the singular property of attracting particles of iron, by an invisible power. The force of this attraction is sometimes so powerful as to raise considerable weights. This mineral has received the name of a *Magnet*, from the Greek word *magnees ;* and hence the term *Magnetism* is used to stand for the phenomena exhibited by this mineral ;—in the same way that the term electricity is applied to the unknown cause of electrical phenomena. This influence may be communicated to some metallic bodies, and particularly to iron and steel.

When a magnet is rolled in iron filings, different quantities of the filings are attached to different parts of its surface. This effect is particularly sensible at two opposite points, where the filings are accumulated in the greatest abundance, standing as it were on end, nearly parallel to each other. These parts are called the *poles* of the magnet.

When a magnet is suspended horizontally by an untwisted thread, or bundle of silk fibres, or when it is made to float on water, it takes a determinate direction. This direction, however, differs in different parts of the earth, being in some exactly in the meridian ; in others, inclining towards the west ; and in others again, towards the east.

If to one of the poles of a magnet thus suspended, a similar pole of another magnet be presented, they will repel each other ; but if the opposite poles are presented, they will attract each other. This is analogous to what takes place when bodies are under the influence of electricity, and hence similar laws of attraction and repulsion are applicable.

To these poles, the names of *north* and *south*, or *boreal* and *austral*, have been applied ; and by Berzelius, *positive* and *negative.— Traité de Chim.* i. 170.

When a steel bar is suspended freely by its centre of gravity, and afterwards carefully magnetized, it will be found not only to place itself in the magnetic meridian, but to assume a position inclined to the horizon. In nothern latitudes, the northern pole of the needle will incline beneath the horizontal plane, and the other will be raised above it. This angle of inclination varies but little at the same place, and is called the *dip of the needle.* There is a zone not far from the equator, where the magnet hangs in a horizontal position ; to the south of this the northern pole will be elevated, and the sourthern will dip.

Although the magnet exerts its force at the distance of several feet, it decreases in strength as the distances increase, but in very different ratios in different magnets. In some the force of attraction seems to be inversely as the square of the distances ; in others as the cubes of the distances ; and so on in other proportions. Its virtue is exerted *in vacuo*, as well as in open air, and without any sensible diminution

of its force by the interposition of the hardest bodies, whose pores it easily pervades.

The magnetic property is found also to reside naturally in nickel and a few other metals. It may be communicated to iron and steel, as follows :

1. *By the contact of a natural magnet.* This is indeed proved by examining the crest of iron filings attached to the poles of the magnet, which will be found to consist of several minute magnets adhering end to end.

Bars of soft iron may be rendered quickly magnetic by the contact of a magnet. Thus, if we suspend a small bar of soft iron to the pole of a magnet, the lower end will immediately acquire magnetic properties. A second and a third bar added to this will adhere to one another, until their total weight exceeds that which the magnet is capable of supporting. When the first bar detaches itself they all fall, and lose, in a great measure, their magnetic powers.

Bars of steel may also be magnetized by the contact of a magnet or magnets, but this is affected with more difficulty ; though the bars retain magnetism much longer. The same magnet may thus successively magnetize any number of steel bars, without losing any portion of its original virtue, if the bars be not too large ; from which it follows that the magnet communicates nothing to the bars, but only developes, by its influence, some hidden principle. [For details of the methods of magnetizing bars of steel, see *Biot's Traité Précis. or Cambridge Course of Physics.*]

2. Besides the contact of a magnet, magnetism may be communicated to iron and steel, *by placing them in the magnetic meridian,—by torsion or twisting, by the blow of a hammer, by pressure, by the act of rotation,* and even, as some have supposed, *by mere exposure to certain rays of light.* [See page 69.]

The *directive power* of the magnet is the most important property which it possesses ; and it is this which has led to the construction of the *Compass,* an instrument wherein a magnetized needle is employed, to ascertain the direction of objects from the point in which it is placed. It is more especially useful in pointing out the course of a vessel when at sea, and out of sight of land : without this valuable invention, it would have been out of our power to have traversed the great oceans, that form so large a portion of the globe.

The directive force of the needle is impaired by the vicinity of large masses of iron. In ships this is a source of much inconvenience, especially in high northern or southern latitudes. To remedy the errors of the needle, resulting from this cause, Professor Barlow contrived an instrument, which is called the *Correcting Plate ;* the utility of which, has been abundantly proved by Capts. Sabine, Parry, and other distinguished naval officers.

Electricity also has the effect of varying the directive power of the needle, and that not only when acccumulated, but as excited by the mere friction upon the glass cover of the compass. Hence needles are in this manner very frequently injured. [See Lieut. E. J. Johnson's valuable observations on local and electrical influences on compasses variously constructed, in *Brande's Jour.* xxi. 274.]

There are several practical applications of the laws of magnetism. Among these may be mentioned, the separation of iron filings from the particles of sand and other substances with which they are often

mixed. A neat apparatus for effecting this object is described in the 28th volume of the Transactions of the London Society of Arts. The same principle has also been applied to the separation of the magnetic ores of iron from silica, pyrites, and other substances which interfere with the process of smelting. A method was patented in England in 1792, which consisted in reducing the crude ore to a coarse powder by means of hammers, rollers, &c., and of separating the metallic particles by the employment of magnetic attraction. [*Repert. of Arts, 1st Ser.* I.] An American patent has also been issued for a similar application of this principle, which cannot fail to be useful in those districts where the magnetic ores of iron are abundant.

Another beautiful application of the laws of magnetism, is the construction of masks of magnetized steel wire, which are now employed by the workmen who are engaged in the pointing of needles; an occupation which was formerly attended with great hazard, in consequence of the fine particles of steel, continually flying off from the grindstone, being inhaled into the lungs.

Magnetism is also employed in certain analyses. The method of oscillations suggested by Coulomb, is one of the most accurate for ascertaining the presence of iron, either in natural or artificial products. We have only to form needles of the substances to be examined, and to make them oscillate between two powerful magnets, and to compare their oscillations with those of needles made of iron, combined with some other substance not magnetic, the relative proportions of the iron and the unmagnetic substance being known.

It only remains to add to this sketch, a few words concerning *Terrestrial Magnetism.*

The earth may be considered as a great natural magnet, and many of the phenomena which we have noticed are due to the power of this magnet. From the experiments which have been made upon the earth's magnetism, it results that there is a line (called the *magnetic equator,*) in which the needle has no dip; that as we proceed from this line, north or south, the dip constantly increases until we arrive at points where the needle is vertical, which are called the *poles*—that there are also lines which cut the magnetic equator, in which the needle has no declination, or points to the true north and south.

The earth, therefore, is a great natural magnet, with poles and a point where the influence of the poles is exactly balanced; hence the directive power and the dip of the needle are due to its influence.

It may be remarked, that although the phenomena of magnetism are manifest only in a few substances, Professor Hansteen has drawn from numerous experiments and observations, the important conclusion, *that every vertical object, of whatever material it is composed, has a magnetic south pole above, and a north pole below.—Edin. Phil. Jour. for* 1826.

REFERENCES. *Biot's Traité, or Cambridge Course of Physics. Renwick's Outlines of Natural Philosophy. Robinson's Nat. Phil. Cavallo's Philosophy. For an account of the Experiments on the peculiar magnetic effect induced in Iron, and on the magnetism manifested in other Metals, &c. during the act of rotation, by Messrs. Barlow, Christie, Babbage and Herschel, See Phil. Trans. for* 1825. *Also, Ann. of Phil.* xxvii. *and* xxviii. *Capt. Kater's valuable directions for constructing Compass Needles, Ann. of Phil.* xviii. 231. *For a description of Barlow's Correcting Plate, see his Essay on Magnetic Attraction, and the value of*

*this Apparatus attested by Capt. Parry, 3d voyage, 65 and 67, Amer. Ed.
Professor Hansteen's Table of the variations of the Magnetic Needle,
Brewster's Edin. Jour.* ix. 264.— *This Journal also contains several other
papers by the same author.   Capt. Sabine, on the Magnetism of the Earth,
Silliman's Jour.* xvii. 154.

ELECTRO-MAGNETISM.

It has already been observed, that electricity, as developed by fric-
tion, has an effect upon the directive power of the needle.   The power
of lightning also, in destroying and reversing the poles of a magnet,
and in giving magnetic polarity to pieces of iron which did not pre-
viously possess it, has long been known.   Attempts were accordingly
made at different times to communicate the magnetic virtue by means
of electricity* or galvanism ; but no results of importance were ob-
tained until the year 1819, when Professor Oersted made his cele-
brated discovery, which constitutes the basis of the science of *Electro-
Magnetism* or *Electro-Dynamics.*

The fact observed by Professor Oersted was, that an electric cur-
rent, such as is supposed to pass from the positive to the negative pole
of a voltaic battery along a wire which connects them, causes a mag-
netic needle placed near it to deviate from its natural position, and as-
sume a new one, the direction of which depends upon the relative po-
sition of the needle and the wire.   On placing the wire above the mag-
net and parallel to it, the pole next the negative end of the battery
always moves westward, and when the wire is placed under the needle,
the same pole goes towards the east.   If the wire is on the same hori-
zontal plane with the needle, no declination whatever takes place; but
the magnet shows a disposition to move in a vertical direction, the
pole next the negative side of the battery being depressed when the
wire is to the west of it, and elevated when it is placed on the east
side.

The *conjunctive wire*† connecting the two poles of the battery, may
consist of any metal ; even a tube filled with mercury is effectual : the
only difference is in the amount of effect produced.   It continues also,
though the conductor be interrupted by water, unless the interruption
be of great extent.   The influence of the wire extends through all sub-
stances, and acts upon the needle beyond, just as with common magne-
tism.

Those forms of the voltaic apparatus which generate *quantity*, are

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* In a paper published by Dr. Franklin in 1750, he observes, " By electricity
we have (here at Philadelphia) frequently given polarity to needles, and rever-
sed it at pleasure."   " A shock from four large glass jars, sent through a fine
sewing needle gives it polarity, and it will traverse when laid on water.   If the
needle, when struck, lies east and west, the end entered by the electric blast
points north.   If it lies north and south, the end that lay towards the north
will continue to point north when placed on water, whether the fire entered at
that end, or at the contrary end."—*Franklin's Works,* iii. 65.

† This term is synonymous with the terms, *connecting* and *communicating wire,*
employed by some authors.   There can be no confusion in regard to them, when
it is remembered that the phenomena of electro-magnetism are solely produced
by electricity in motion.   Whatever, therefore, forms the union between the
zinc and copper plates used to exhibit these effects, is, for convenience, called
the *conjunctive* or connecting wire.

such as produce the most decided electro-magnetic effects; they appear to be independent of tension, and hence a single pair of very large plates, is more effectual than a number of small ones. Batteries constructed of one or a few pairs of large plates, have hence been called *magnetomotors*.

I shall present an outline of the principle facts of electro-magnetism under the following heads, viz.

1. Action of the conjunctive wire upon the magnet.
2. Action of the conjunctive wire upon soft iron and steel.
3. Action of two conjunctive wires upon each other.
4. Action of the electro and steel-magnet upon the conjunctive wire.
5. Action of the earth's magnetism upon the conjunctive wire.

I. *Action of the conjunctive wire upon the magnet.*—It has already been observed, that when a wire connects the opposite poles of a voltaic battery, a magnetic needle placed near it is made to deviate from its natural position. These facts, discovered by Oersted, have been confirmed by the experiments of various other philosophers. It has also been shown by Ampere, that the pile itself acts in the same manner as the conjunctive wire, and his views of the phenomena led him to the construction of an instrument which, at the same time that it proved this action, was shown to be of great value in experiments on currents of electricity. This was merely a magnetic needle, but from the use to which it was applied, was called a *Galvanometer*. When placed near a pile or trough, in action, having its poles connected either by a wire, or by introducing them into one cell, it immediately moved, becoming obedient to the battery, in the same manner as to the connecting wire : and the motions were such as if the battery were simply a continuation or part of the wire.

The action of the conjunctive wire upon the magnet, can be more advantageously exhibited by the instrument invented by Professor Schweigger, of Halle, and called the *Electro-magnetic Multiplier*. This instrument consists of brass wire, wound with silk, so as to prevent the electricity from passing laterally, and wound upon the hand or a book, fifty, or an hundred or more times ; the delicacy of the apparatus being in proportion to the number of turns.—These are now held in

their place by threads of silk, and the two ends of the wire are left free. We have thus an oval bundle of wires, through which, when the ends are connected with an active battery, the current of electricity passes. If now we place a freely suspended magnetic needle in the middle of this oval multiplier, and then connect the two ends of the wires with the two opposite poles of a battery, the needle, after several oscillations, becomes stationary at right angles to the oval, the influence of terrestrial magnetism being surmounted by that of the multiplier. When this instrument consists of 60 or 100 turns, the needle may be made to deviate by disks of zinc and copper, an inch in diameter, and merely united by paper, moistened by any saline solution, or even by saliva.—*Ann. of Phil.* xxi. 436.

Various modifications of this apparatus have been proposed ; that invented by Professor Henry and described by him in the first volume of the Transactions of the Albany Institute, is one of the most convenient.

It appears therefore, that the wire connecting the two opposite poles of a voltaic battery, and the battery itself, during the passage of electricity, exerts a certain action upon the magnetic needle,—and that the force which is thus exerted by the conjunctive wire, is at right angles to its axis.

The conjunctive wire is also capable of attracting and repelling the poles of a magnet. If, when the magnet and connecting wire are at right angles to each other, the latter passing across the centre of the former, the wire be moved along the needle towards either extremity, attraction will take place between the wire and the adjacent pole; and this will occur, though the same point of the wire should be presented in succession to both of the poles. Again if the position of the poles of the needle be reversed, they will be repelled by the same point of the wire which had previously attracted them.—See *Faraday's Historical Sketch of Electro-Magnetism, in Ann. of Phil.* xviii. 198.

Any wire, through which a current of electricity is passing, has a tendency to revolve round a magnetic pole, in a plane perpendicular to the current; and that, without any reference to the axis of the magnet, the pole of which is used. A magnetic pole also has a tendency to revolve round such a wire.

Suppose the wire perpendicular, its upper end positive, or attached to the positive pole of a voltaic battery, and its lower end negative; and let the centre of a watch-dial represent the negative pole; if it be a north pole, the wire will rotate round in the direction that the watch hands move; if it be a south pole, the motion will be in the opposite direction. From these two, the motions which would take place if the wire were inverted, or the pole changed or made to move, may be readily ascertained, since the relation now pointed out remains constant.

These motions are exhibited in an apparatus devised by Mr. Faraday, or perhaps still better by the revolving cylinders of Ampere. They consist of a cylinder of copper b, about two inches high, and one and three fourths internal diameter, within which is a smaller cylinder about one inch diameter a, also of copper.

The two cylinders are fixed together by a bottom, having a hole in the centre the size of the smallest cylinder, leaving a circular cell which may be filled with dilute acid. A piece of strong copper wire is fastened across the top of the inner cylinder, with a point projecting downward which rests upon p, one of the poles of a strong horse shoe magnet upon which it can freely turn. A cylinder of zinc about an inch and a quarter in diameter and open at each end with the wire c soldered at opposite sides
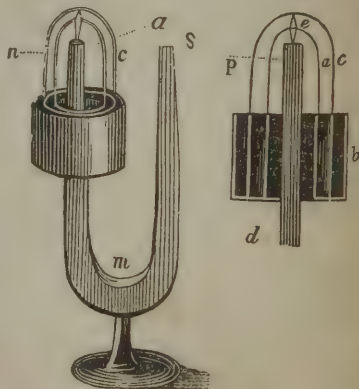
turns on the pivot *e*. The cylinder of zinc hangs within the copper without touching it. If now diluted sulphuric or nitric acid be poured into the cup *b* the zinc cylinder will revolve in one direction and the copper cup in a contrary direction. If the apparatus be placed upon the opposite pole of the magnet these motions will be reversed.

II. *Action of the conjunctive wire upon soft iron and steel.*— It was about the same time ascertained, both by Sir H. Davy and M. Arago, that magnetism may be developed in steel, not previously possessing it, by being placed in the electric current, and may even be excited by the connecting wire itself. Both philosophers ascertained, independently of each other, that the conjunctive wire attracts iron filings, and collects sufficient to acquire the diameter of a common quill. As soon as the connection is broken, the filings drop off, and the attraction diminishes with the decaying energies of the battery.

In Sir H. Davy's experiments, similar effects were produced by common electricity. With a Leyden battery of seventeen square feet, discharged through a silver wire one-twentieth of an inch diameter, he rendered bars of steel two inches long and from one-tenth to one-twentieth thick, so magnetic as to lift up pieces of steel wire and needles ; and the effect was communicated to needles at the distance of five inches from the wire, even with the intervention of water or thick plates of glass or metal.— *Phil. Trans. for* 1821, or *Ann. of Phil.* xviii. 81, xix. 1.

The theory of Ampere, that magnets are only masses of matter, around the axis of which electrical currents are moving in closed curves, led M. Arago to expect a much greater effect, if the connecting wires were placed in the form of a spiral, and the piece to be magnetized were placed in its axis. This idea was amply verified by experiment. Having made some of these helices, one was connected by its extremities with the poles of a voltaic battery, and then a needle wrapped in paper, placed within it ; after remaining there a few minutes, it was taken out and found to be strongly magnetized ; and the effect of a helix above that of a straight connecting wire, was found to be very great. If the wire after being formed into a helix, be bent back, so as to return in a straight course in the interior of the cylinder, with the usual precautions against contact, we obtain a very perfect accordance with the condition of a magnetic cylinder ; and to such arrangements the term *Voltaic Magnets* may be applied as being preferable to that of *Electro-dynamic Cylinders*, given to them by Ampere.

This application of the theory of Ampere, has led to the most interesting and remarkable results—having made us acquainted with a method of magnetizing soft iron to an extent heretofore unknown.

It was found that when the conjunctive wire was wound around a bar of iron, bent in the form of a horse-shoe, while the battery was in action, the iron became quite powerfully magnetic; but to produce these effects, it was supposed that powerful voltaic instruments were required. The first simplification of apparatus for this purpose, was proposed by Mr. Sturgeon, of Woolwich, [*Ann. of Phil.* xxviii. 357,] who was enabled by his apparatus to render a horse-shoe capable of supporting nine pounds, when the opposite ends of the wires were united with the poles of his voltaic arrangement.

Dr. Moll, of Utrecht, in repeating these experiments, used a large voltaic surface. He first employed a soft iron wire, bent in the form of a horse-shoe ; the length of the horse-shoe being about eight and a

half inches, and one inch in diameter. A copper wire about one eighth of an inch in diameter was twisted or coiled eighty-three times round the iron, from right to left. The two ends of the wire were connected with the opposite poles of a galvanic apparatus, consisting of one single copper trough, in which a zinc plate, having a surface of about eleven square feet, was immersed. When the voltaic apparatus was rendered active, the horse-shoe was capable of supporting fifty pounds. A larger horse-shoe, about twelve inches and a half high and two and a quarter inches in diameter, and weighing about twenty-six pounds, coated with silk and wound round, at first, with forty-four turns of brass wire, the acting voltaic surface being the same as before, supported 135 pounds; with forty turns of iron wire it supported 154 pounds.— *Brewster's Edin. Jour. N. S.* iii. 209, *and Silliman's Jour.* xix. 329.

But the most interesting experiments of this kind, are those of Professors Henry and Ten Eyck; the object of which was not merely to impart to soft iron its greatest magnetic effect, but with a very small galvanic surface. Around an iron horse-shoe, about nine and a half inches high and two inches square, and weighing 21 pounds, 540 feet of copper bell-wire, previously covered with silk or cotton thread, were wound in nine coils of 60 feet each. These coils were not continued around the whole length of the bar, but each strand of wire occupied two inches, and was coiled several times backwards and forwards over itself; the several ends of the wires were left projecting, and all numbered, so that the first and last end of each strand might be easily distinguished. In this manner one combination of wire or more, could be made by merely uniting the different projecting ends.

With a single battery, consisting of two concentric copper cylinders, with zinc between them, having a surface of 2-5ths of a square foot, and which needed one half pint of dilute acid for its submersion, the horse-shoe supported, when the extreme and opposite ends of all the wires were soldered to the zinc and copper, 650 pounds. But when a zinc plate of twelve inches long and six wide, and surrounded by copper, was employed, the horse-shoe supported 750 pounds.—*Silliman's Jour.* xix. 400.

Still more recently these gentlemen have constructed a magnet, consisting of a soft iron horse-shoe, weighing fifty-nine and a half pounds, and coiled with seven hundred and twenty-eight feet of copper bell-wire, in twenty-six strands, which with a zinc surface of four seven-ninth square feet, surrounded by copper, *supports, when the battery is in action,* 2,062 *pounds.*—*Silliman's Jour.* xx. 201.

The annexed cut exhibits a simple form of this apparatus. A piece of soft iron is bent into the form of a horse-shoe, and has copper wire, properly coated, twisted around the bar at right angles to its axis, and an armature of soft iron, to which a weight may be attached, is fitted to its extremities. On connecting the
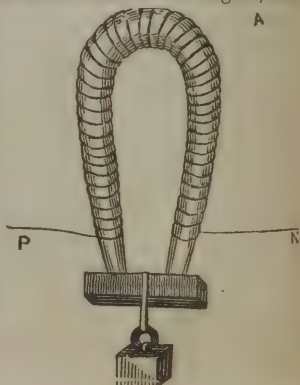
ends of the wire P and N with a simple voltaic circle, even of small size, the soft iron instantly becomes a powerful magnet.

III. *Action of two conjunctive wires upon each other.*—It was observed by Ampere, that when two conducting wires were so arranged as that one or both of them were allowed a certain freedom of motion, they either attracted or repelled each other, according as the electric current which was transmitted was moving in the same or in opposite directions in the two wires. If, for example, two wires, which are transmitting currents of electricity, be situated within a certain distance, and parallel to each other, and if we suppose the current of positive electricity to be passing from left to right, in both the wires, they will manifest an attraction for each other. The same tendency of attraction will also appear when the positive currents are both moving in the contrary direction, that is from right to left. But if the current in one wire be moving in a direction opposite to that of the current in the other wire, in that case a repulsive action will take place between the two wires. These were found to be constant and invariable effects of the transmission of electricity along conductors; and they were manifested equally, whether the two currents were obtained from separate voltaic batteries, or were only two portions of the same current in different parts of its course.—*Quarterly Review*, xxxv.

The contrast between these attractions and repulsions, and those usually called electrical, is very striking. These take place only when the circuit is completed; those only when it is incomplete. The attractions take place between the similar ends of the wires, and the repulsions between the dissimilar ends ; but the electrical attractions take place between dissimilar ends ; and the repulsions between similar ends. These take place *in vacuo*, but those do not. When the magnetic attraction brings the two wires together, they remain in contact ; but when electrical attraction brings two bodies together, they separate after the contact.

It is evident, therefore, that these effects cannot be ascribed to electrical action ; it has therefore been regarded as a magnetic effect, and an attempt has been made to account for it upon the principle of the vertiginous action of magnetism around the axis of the conjunctive wire. But this, as we shall presently see, is assumed by Ampere, as an ultimate fact.

IV. *Action of electro and steel-magnets upon the conjunctive wire, or Volta and Magneto-electric Induction.*—For most of the facts upon this new and interesting branch of Electro-Dynamics we are indebted to Mr. Faraday. It has been shown that when an excited electric is brought near to an insulated body, electricity is *induced* in the body. After a series of experiments, the distinguished philosopher just named, succeeded in proving that electro-magnetic phenomena could also be exhibited by induction. A copper wire 203 feet in length was passed in the form of a helix round a large block of wood, and an equal length of similar wire was wound on the same block and in the same direction, so that the coils of each helix should be interposed, but without contact, between the coils of the other. The ends of one of the helices were connected with a galvanometer, and the other with a strong voltaic battery, with the view of ascertaining whether the passage of a voltaic current through one helix would induce a current in the adjoining helix. It was found that the galvanometer needle indicated a current at the moment both of completing and breaking the

circuit, but that in the interval no deflection took place; and similarly the induced current readily magnetized a sewing needle, while the voltaic current along the inducing helix was in the act of beginning and ceasing to flow, but at no other period. By varying the experiment the same result was obtained: an electric current transmitted from a voltaic battery through a conducting helix does not induce a current in an adjoining helix, except at the moment of making or breaking the voltaic circuit. In the former case the direction of the induced current is opposite to that of the inducing current, and in the latter case it is the same. This phenomenon is distinguished by Mr. Faraday under the name of *Volta-electric Induction.*

In continuing these researches, it was also found that the inducing power of a magnet greatly exceeds that of an electric current. There are various arrangements of apparatus for the purpose of illustrating this fact. Perhaps one of the most convenient consists of a hollow cylinder of pasteboard, round which two compound helices were adjusted. On transmitting an electric current through one helix, the other deflected the galvanometer and magnetized a needle, as in the experiment just described; but when a cylinder of soft iron was introduced into the pasteboard case, and a voltaic current transmitted as before, the effect on the galvanometer was much greater. The action in this last experiment is distinguished by the name of *Magneto-electric Induction.*

Upon carefully reviewing these experiments and comparing them with those already described, in the remarks concerning the condition of the conjunctive wire and its action upon soft iron, it is evident that the induced wire is in the same electric state as that which unites the two poles of the battery. Thus it magnetizes steel, it deflects the magnet; and by connecting a frog's leg with the induced wire it is thrown into spasms, and by arming the ends of that wire with points of charcoal and separating them at the instant the voltaic circuit is broken or restored, sparks of electricity are obtained. A voltaic current circulating around a bar of soft iron converts it, as we have seen, into a temporary magnet, and it is to this magnet that most of the induced electricity is to be ascribed. Mr. Faraday rendered this certain by surrounding a cylinder of soft iron with one helix connected with the galvanometer, and converting the soft iron into a temporary magnet, not by a voltaic battery, but by placing at each end of the cylinder the opposite pole of a magnet. During the act of applying the magnetic poles to the iron, the galvanometer needle was deflected; and the deflection was reproduced, but in an opposite direction, when the magnetism of the iron was ceasing by the removal of the magnet. So also when a helix was wound on a hollow cylinder of pasteboard, and a real magnet was introduced, the galvanometer was deflected: the needle then remained quiescent so long as the magnet was left in the cylinder; but in the act of its removal, the needle was again deflected, though as usual in the opposite direction.

Thus it appears that while magnetism may be induced by an electric current, electricity may also be induced in a wire by a magnet. In consequence of the intimate relations which are thus established between galvanic and magnetic action, it was supposed that the electric spark could be obtained from the magnet itself. Several arrangements of apparatus are now constructed, which at first might seem to confirm this conjecture. But the electrical phenomena which they exhibit, may all be referred to the principle of induction which has

past been explained. By surrounding the middle of the keeper or armature of a common steel magnet with a helix of copper wire wound with silk, and connecting one of the ends of the wire with a cup of mercury and removing the other at the moment the armature of soft iron is withdrawn from the magnet, a spark is visible ; as also when the armature is applied and the contact of the conducting wire restored. Of the different forms of apparatus constructed for the purpose of showing these effects, one of the most convenient is that of Mr. Saxton, described in the Journal of the Franklin Institute for 1834. In this apparatus the keeper is made to revolve upon the ends of the magnet and around its axis ; and by a peculiar arrangement of the coils of copper wire which surround it, water may be rapidly decomposed, and shocks communicated to the mouth and tongue. Dr. Emmet, with an other arrangement, has succeeded in giving shocks so powerful that they can scarcely be taken through the arms and shoulders without great inconvenience. [*Silliman's Jour.* xxvi, 313.] And Dr. Ritchie has described a neat apparatus for firing an explosive mixture of oxygen and hydrogen gases. But I must omit further details and refer those who wish to examine these and other allied topics, to the papers of Mr. Faraday, Dr. Ritchie, Mr. Forbes, and others, most of which are published in the recent volumes of the London Phil. Mag. and in Silliman's Journal. The late edition of Dr. Turner's Chemistry also contains a well digested summary of the recent discoveries in Electro-Magnetism, to which I acknowledge myself largely indebted in the preceding sketch.

V. *Action of the earth's magnetism upon electric currents.*—Led by his elaborate views of this subject, Ampere was induced to substitute terrestrial magnetism for the magnet he had previously used in experiments on the wire. His conclusions were verified upon finding that a conducting wire, bent into the form of a circle, when free to move, always assumes, by the electro-magnetic action of the earth, a position in a plane which is perpendicular to the magnetic meridian.

This fact can be shown in a striking manner, by a small instrument called *De la Rive's Ring.* It consists of a small voltaic combination, or battery, attached to a piece of cork ; the zinc plate is half an inch wide and three inches long, and passes through the middle of the cork, two and a half inches below and half an inch above it ; the slip of copper is the same width as the zinc, but about twice as long ; it passes through the cork on both sides of it, and being thus opposed to both surfaces, it forms a little battery, on the principle of Dr. Wollaston's. A piece of copper wire, covered with silk thread, is rolled five or six times and tied together so as to form a ring, about an inch and a half in diameter ; the ends of the wire are connected, one with the zinc, and the other with the copper slip or plate, above the cork. Now when this little battery is placed in water, slightly acidulated with sulphuric or nitric acid, the ring becomes magnetic, and on

presenting a magnetic bar to it, which is strongly charged, it will be attracted and repelled, according as one or the other of the poles is opposed, or as one or the other side of the ring is presented to the bar.
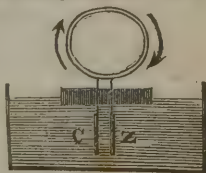
If instead of connecting the copper and zinc by a ring, it is done by a helix of copper, and the instrument then floated on dilute acid, the

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helix becomes magnetic; its extremities act like the opposite poles of a magnetic needle, being attracted or repelled by the opposite ends of a magnetic bar, and it settles in a north and south position, in the same manner as a common magnetic needle.

THEORY OF ELECTRO-MAGNETISM.

Different theoretical views of the phenomena of Electro-Magnetism have been offered. But those of M. Ampere are the most extensive and precise, and have been tested by the application of facts and calculations very far beyond any of the rest. They have also been found a safe guide in experiment, and many of the most interesting facts of the science are direct consequences from them. Of these views the following is a very brief outline; but as the theory of two electrical fluids is adopted by Ampere, they are here made to conform with that of one fluid employed throughout this work.

When a wire of any metal connects the opposite poles of a voltaic battery in action, it is supposed that a current of electricity is circulating from the positive to the negative side of the battery, and it is only when electricity is thus moving, that magnetic phenomena are produced.

While others attempt to explain the attraction which is observed between currents when they move parallel to each other in a similar direction, and the repulsion between currents moving parallel to each other in opposite directions, Ampere assumes these as the fundamental or ultimate facts.

Ampere supposes that all magnetic bodies, and the globe of the earth among the number, derive their magnetic properties from currents of electricity continually circulating among the parts of which they are composed, and having, with respect to the axis of these bodies, one uniform direction of revolution.

In order to render these views more precise, let us conceive a slender cylinder of iron, intersected by an infinite number of planes, perpendicular to the axis, so as to divide it into as many circular disks, successively applied to each other, as represented in the annexed diagram: let us now imagine that, in consequence of some unknown action among the particles composing these circles, a current of electricity is perpetually circulating in their circumferences, as if they had composed a voltaic circuit. Let us suppose the direction of these currents to be the same throughout the whole series of circles: the cylinder thus constituted may be considered as a magnetic filament; that extremity in which, when uppermost, the current of positive electricity is moving in a direction contrary to the hands of a watch, being the one which has the northern polarity, that is to say, which, when suspended as in a compass needle, points to the north.

Setting out then, with the assumptions that parallel currents attract one another when their directions are the same, and repel one another when opposite; and that a magnet consists of an infinite number of circular currents of electricity, all the facts of the science, now known, can be easily explained.

We have seen that when the conjunctive wire is brought near to a magnetic needle, it is deflected to the east or west according as the wire is brought above or below the needle. In order to understand

this fact, and the course of the deflection, we have only to suppose electric currents passing round the needle from west to east as represented. Now when the conjunctive wire is brought over, and in a direction parallel to the magnetic north and south, the current of positive electricity passing from north to south, the north end of the needle will be deflected to the east, because the current in the wire and those in the magnet will then move in similar directions. For the same reason also, when the wire thus arranged, is brought under the needle, it will be deflected to the west, because then also the currents will be in similar directions. When the position of the conjunctive wire is reversed, that is, when the supposed electric current passes from south to north, it will, when brought over the needle, cause it to deviate to the west ; when brought under it, to the east. All these results precisely accord with experiments, and they are also supported by the most exact mathematical calculations.

The revolutions of the wire around magnets were regarded by most philosophers as indicative of a rotary tendency being an ultimate fact, but they will be found upon an attentive examination to be direct consequences of Ampere's theory ; and are indeed, among the strongest confirmations of its truth. So also the phenomena of electro-magnetic induction, and the action of terrestrial magnetism upon electrical currents, are precisely such as might have been deduced from it.

REFERENCES. *Faraday's Historical Sketch of Electro-Magnetism, up to 1822 Ann. of Phil. xviii. 195, 274, xix. 107. Professor Oersted on Electro-Magnetism, Ann. of Phil. xviii, 321—contains his own account of his theory, and his objections to that of Ampere. Professor Green, of Philadelphia, on Electro-Magnetism. (This little work contains a good account of the principal facts of the science up to 1827, with descriptions and plates of apparatus, &c.) Art. Electro-Magnetism in the Quarterly Review, xxxv.—contains an exposition of the theory of Ampere, shewing its application to all the facts of the science. Professor Cumming's Manual of Electro-Dynamics. Barlow's Essay on Magnetic Attractions. Watkins' popular Sketch of Electro-Magnetism. The article Electro-Magnetism, in the Library of Useful Knowledge, by Dr. Roget.*

THERMO-ELECTRICITY.

Thermo-electric phenomena are those which result from currents of electricity, which can be excited in metals by mere variations of temperature. Seebeck demonstrated the existence of these currents in 1821, and this observation was one of the first, as well as the most ingenious applications, of the discovery of Oersted.

If a magnetic needle be placed upon a pivot within a rectangle, formed of a bar of antimony or bismuth, with a slip of copper or a copper wire soldered to each of its extremities, and the heat of a lamp applied to one end of the bar, the needle will be deflected and tend to place itself at right angles to the magnetic meridian. If that end be allowed to cool, the needle returns to its former position, and if now the opposite end of the bar be heated, the needle is deflected in a direction contrary to that in the former case. Similar phenomena will also be observed when either of the ends are cooled down below the natural temperature.

Thermo-electricity may also be developed in a homogeneous metallic mass, or in two distinct masses of the same metal unequally heated at their point of contact. Nor is it confined to the simple metals ;—char-

coal, plumbago and some of the metallic sulphurets, are capable of this species of excitation.

The metals compose a thermo-electric series, of which bismuth and antimony are the extremes, and are the most efficacious within certain limits.

Rotatory motion may also be produced by thermo-electrics, as first shown by Professor Cumming. Platinum and silver wires soldered together in a circular form, rotate, when poised upon a magnet and heated by a lamp.

The thermo-electric current appears to be incapable of passing through fluid non metallic conductors, of heating wire placed in its circuit, or of magnetizing steel or forming a thermo-electric magnet; and it therefore seems to have no assignable tension.*—*Cumming's Report.*

It has been supposed that a thermo-electric combination might be employed as a very delicate thermometer; and an instrument has been constructed by M. M. Nobili and Melloni, which they denominate a *Thermo-multiplier*, and which consists of such a combination, susceptible of excitation from the feeblest conceivable application of heat, and connected with a delicate galvanometer, which gives a measure of the effect produced, and consequently of the heat. [*Ann. de Chim. Oct.* 1831.] This apparatus they have applied to the examination of the different reflecting, absorbing and radiating power of surfaces. But according to Professor Cumming the ratio between the temperatures and the corresponding deviations of a needle, in the thermo-electric circuit, is not invariable, the deviations increasing slower than the temperature, the law of which deviation is unknown; and hence a pyrometer constructed on thermo-electric principles gives inaccurate indications.

The theoretical views which have been heretofore offered, are applicable to the phenomena of thermo-electricity.

REFERENCES. *Experiments on Thermo-Electricity by Fourier and Oersted, Ann. of Phil. xxi. 439. Professor Cumming's Report on the same, published in the Reports of the British Association for 1832. Sturgeon's papers in the Phil. Mag. and Ann. for 1831. Emmet upon Caloric as a cause of Galvanic Currents, Sill. Jour. xxv. 269. Most of the general works referred to under the last head, contain notices of Thermo-Electricity.*

INORGANIC CHEMISTRY.

PRELIMINARY REMARKS.

Having in the preceding chapters treated of the general chemical powers and the laws which govern them, I come next to the chemical

* Mr. Watkins has recently announced that with a pair of metallic elements, consisting of one bismuth and one antimony, weighing each 0.5 grains, and measuring 0.5 of an inch long, and 0.12 in diameter, when their extremities were unequally heated, he has obtained, with a Henry's flat ribbon coil, a very perceptible and brilliant spark.—*Lond. & Edin. Phil. Mag.* xi. 398.

history of the elementary principles, and of those compound bodies which are not the product of organization.

The number of substances at present considered as elementary, is about fifty-four. Of these, several possess certain properties in common, although they are all specifically different. Not more than two or three of the whole number are found in an uncombined state, in nature, but are met with under various forms of combination. At ordinary temperatures four of these bodies exist in the gaseous form, two are liquid, while the rest are solid. And finally, twelve of them are not metallic, while all the rest possess those properties which characterize the metals.

The following is a table of these elementary bodies, arranged in the order in which they are treated of in this work.

Non Metallic Bodies.	Metals.		
1. Oxygen.	13. Potassium.	28. Zinc.	43. Tellurium.
2. Chlorine.	14. Sodium.	29. Tin.	44. Bismuth.
3. Bromine.	15. Lithium.	30. Cadmium.	45. Copper.
4. Iodine.	16. Barium.	31. Nickel.	46. Lead.
5. Fluorine.	17. Strontium.	32. Cobalt.	47. Mercury.
	18. Calcium.	33. Arsenic.	48. Silver.
	19. Magnesium.	34. Molybdenum.	49. Gold.
6. Hydrogen.	20. Aluminum.	35. Chromium.	50. Platinum.
7. Nitrogen.	21. Glucinum.	36. Vanadium.	51. Palladium.
8 Sulphur.	22. Yttrium.	37. Tungsten.	52. Rhodium.
9. Phosphorus.	23. Zirconium.	38. Antimony.	53. Osmium.
10. Carbon.	24. Silicium.	39. Uranium.	54. Iridium.
11. Boron.	25. Thorium.	40. Columbium.	
12. Selenium.	26. Manganese.	41. Cerium.	
	27. Iron.	42. Titanium.	

Before proceeding to a notice of these individual substances, it may be proper to explain the principles upon which the nomenclature, now generally adopted by chemists, is founded.

When bodies unite with oxygen, two sets of compounds are produced, differing in many respects from each other: the one called *oxides* or *satifiable principles ;* the other *acids* or *salifying principles.* The oxides differ from the acids in the want of the sour taste which generally belongs to the latter, and in their not changing vegetable blue colours to red; but they are better characterized by the fact, that they combine with acids and form bodies which are termed salts. In some cases the oxides possess properties termed *alkaline ;* but there are both acids and alkalies which do not contain oxygen.

Oxygen may combine with a body in several proportions, and form both oxides and acids. If there be many oxides of the same base, the Greek numerals are prefixed to express the different proportions of oxygen, as *prot*-oxide, *deut*-oxide *trit*-oxide, and *per*-oxide ; the latter always expressing the highest degree of oxidizement in oxides.

When two acids are formed by the union of different proportions of oxygen, that which contains the smallest quantity is designated by the termination *ous ;* the other by the termination *ic.* Thus *nitrous* acid contains four proportions of oxygen ; *nitric* acid five proportions. The acid containing a still less amount of oxygen than the nitrous, is called the *hypo*-nitrous. And if, as is the case with the sulphurous

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and sulphuric acids, there be an acid intermediate, it is called the *hypo*-sulphuric.

The compounds of chlorine are called *chlorides ;* of bromine, *bro*-*mides ;* of iodine, *iodides ;* and of fluorine, *fluorides ;* when they do not possess acid properties. When they form more than one such compound with a body, or when the compound is acid, the principles already laid down will apply.

Many acids are formed by the union of hydrogen with other bodies. The name of such acids has the usual termination, the term *hydro* being prefixed ; as *hydro*-chloric, *hydri*-odic.

In the compounds of non-metallic combustibles, with metals, the termination *uret*, is added ; thus sulphur and iron form *sulphuret of iron*, &c.

When an acid combines with any salifiable basis, if the resulting compound does not effect either the tests of acids or alkalies, it is called a *neutral salt.* Acids terminating in *ous,* when they combine with alkalies or oxides, change their termination into *ite ;* and acids terminating in *ic,* change it to *ate.* Thus, sulph*ite* of soda consists of sulph*urous* acid and soda ; sulph*ate* of soda, of sulphur*ic* acid and soda. A salt, in which two proportions of an acid are combined with one of a basis, has the same term *bi* prefixed. Thus we have a carbonate and a *bi*-carbonate of soda.

When an acid combines with a protoxide of a metal, the salt has the term *proto* prefixed ; and when with a peroxide, the term *per ;* thus we have a *proto*-sulphate and a *per*-sulphate of iron.

By carefully studying the principles which have thus been briefly laid down, the learner will find his progress in the knowledge of chemical compounds much facilitated. It should be remarked, however, that although generally applicable, there are occasional instances of deviation from these rules.

CHAPTER VI.

SUPPORTERS OF COMBUSTION, OR ELECTRO-NEGATIVE BODIES.

The first five bodies enumerated in the preceding table, namely, OXYGEN, CHLORINE, BROMINE, IODINE, and FLUORINE, are usually called *Supporters of Combustion.* They have also been denominated *Electro-Negative Bodies ;* a term expressive of their supposed electrical condition. They are remarkable for the tendency they have, not only to combine with one another, but with almost all bodies below them in the table ; and their union, particulaly that of oxygen, is generally accompanied with the extrication of more or less of heat and light, and constitutes the well known phenomena termed *Combustion.*

SECTION I.

OXYGEN.

Atom. Num. 8—*Symb.* O— *Sp. gr.* 1·111 air.= 1.*

' SYN. *Dephlogisticated Air*—Priestley. *Empyreal Air*—Scheele.

Discovered by Priestely, in 1774; but received its present name from Lavoisier.

PROPERTIES. In the most simple form in which we can procure it, it is gaseous, insipid, colourless, inodorous, a powerful supporter of respiration and combustion ; sparingly absorbed by water ; when suddenly compressed, emits light and heat ; refracts light less than any other gas.

A supporter of respiration and animal life. This can be shown by confining a small animal, as a mouse, in a vessel of oxygen gas and another in a vessel of the same size, filled with common air. The animal in the former, will live thrice as long as in the latter. Or if we place a glow-worm within a jar of oxygen gas, in a dark room, the insect will shine with much greater brilliancy than it does in atmospheric air, and appear more alert.

A powerful supporter of combustion.—This can be shown by several interesting and brilliant experiments. Thus a lighted taper, when introduced into a vessel of this gas, burns with great brilliancy, and if the taper be blown out, and let down into a vessel of it while the snuff remains red hot, it instantly kindles with a slight explosion. Lighted charcoal emits beautiful scintillations in oxygen gas, and phosphorus burns with such splendour that the eye cannot bear its impression. Even iron wire or a steel watch spring, when formed into a coil and heated at one end to redness, undergoes rapid combustion in it.

It is important to notice that in all the foregoing experiments the volume of the oxygen gas has diminished during the combustion.— This is owing to its combination with the burning body. Oxygen gas is supposed to be a compound of oxygen, light and heat. During combustion in it, the light and heat are given out, and there remains a compound of solid oxygen with the combustible. Thus when iron wire is burned in oxygen gas, light and heat are evolved, and there remains a substance, which, upon examination, proves to be an oxide of iron, composed of oxygen and iron, and the increase of weight in the iron is exactly equal to the diminution of weight in the oxygen gas. The same thing occurs during the combustion of phosphorus, sulphur, carbon, &c. in this gas, though in these cases acids, instead of oxides, are formed.

Respiration has the same effect upon oxygen as combustion. If an animal be confined in a limited quantity of atmospheric air, it will at first feel no inconvenience ; but as a portion of oxygen is withdrawn at each inspiration, its quantity diminishes rapidly, so that respiration soon becomes laborious, and in a short time ceases altogether. Another

* I have endeavoured to consult the convenience of the student by placing under the name of each substance its equivalent or atomic number, the symbol by which it is expressed, and its specific gravity.

animal introduced into the same air, expires in the course of a few seconds, and if a lighted candle be immersed in it, the flame will be extinguished.

NATURAL STATE. Oxygen gas can scarcely be said to exist in a separate state in nature. In some saltpetre caves, perhaps, there is an excess of it, over that which commonly forms atmospheric air.

EXTRACTION. This gas may be obtained by heating to redness any substance which contains a large proportion of oxygen, as the chlorate or nitrate of potassa, peroxide of manganese, and red lead. Chlorate of potassa furnishes the most pure gas; but this requires more cautious management. Peroxide of manganese is generally employed. This is to be heated to redness in a gun-barrel or iron retort, to which a tube is attached. The gas is collected over water. The first portions should be rejected as containing atmospheric air, and sometimes carbonic acid, owing to the impurity of the manganese.* The gas should always be tested with a taper before it is collected for experiment.

The rationale of all these processes accords with the views before given, and will be readily understood. Chlorate of potassa, peroxide of manganese, and red lead, contain a large proportion of oxygen.— Upon the application of heat a part of this oxygen is rendered gaseous and it then escapes.

TEST. M. Kastner has proposed protoxide of iron as a test for the presence of oxygen in gaseous mixtures.—*Phil. Mag. and Ann.* v. 235.

ACTION UPON THE ANIMAL ECONOMY. Although oxygen gas is essential to the support of animal life, it appears, when pure, to cause so great a degree of excitement in the pulmonary organs as to render it hazardous to breathe it for any length of time. Thenard relates a case in which it proved fatal. And, in an experimental inquiry into the physiological effect of oxygen gas upon the animal system, by Mr. Broughton, the author shows that the symptoms induced by its respiration are analogous to those which follow the absorption of certain poisons into the system.—*Phil. Mag. and Ann.* v. 383. *Brande's Jour. N. S.* vii. 1.

USES. Oxygen is an essential part of the atmosphere, is one of the elements of water, and enters into the composition of most of the rocks which form the crust of the globe. It exists also in most animal and vegetable substances, and is indispensable to the existence of all the beings that live on the surface of the globe.

REFERENCES. *Scheele on air and fire. Priestley on Airs. Lavoisier's Elements of Chemistry. Thenard describes an apparatus for showing the evolution of Light by the compression of Oxygen Gas, Traité de Chim.* i. 181. *A convenient apparatus for procuring Oxygen Gas, from Chlorate of Potassa, is described and figured by Berzelius, Traité de Chim.* i. 207. *On the specific gravity of Oxygen, see Thomson's First Prin. where the estimate of Dr. Prout, as above given, is confirmed.*

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* The carbonate of lime to which this is due, may be separated by washing the manganese with dilute muriatic acid until effervescence ceases, or the carbonic acid may be separated by washing the gas in lime water.

SECTION II.

CHLORINE.

Atom. Num. 35·45—*Symb.* Cl—*Sp. gr.* 2·47 *air*=1.

SYN. *Dephlogisticated Marine Acid*—Scheele. *Oxymuriatic Acid.*

This substance was discovered by Scheele, in 1774. It derives its present name from the Greek *chloros, green,* in allusion to its colour.

PROPERTIES. Gaseous, having a yellowish-green colour, an astringent taste and disagreeable odour ; one of the most suffocating of the gases, exciting spasms and great irritation of the glottis, even when considerably diluted with air ; emits light and heat when strongly and suddenly compressed ; under a pressure of four atmospheres becomes a limpid liquid of a bright yellow colour ; is absorbed by cold water, from whence it can again be driven by heat ; supports combustion ; has a strong attraction for hydrogen ; discharges animal and vegetable colours, when water is present ; and is a powerful disinfectant.

Chlorine is absorbed by cold water.—Cold recently boiled water, at the common pressure, absorbs twice its volume of chlorine. Hence a solution of chlorine may be easily made by transmitting a current of the gas through cold water. It has the taste, colour and most of the other properties of the gas itself. When moist chlorine gas is exposed to a cold of 32° F. yellow crystals are formed, which consist of water and, chlorine in definite proportions. They are composed, according to Mr. Faraday, of one atom of chlorine, and ten atoms of water, and have received the name of *Hydrate of Chlorine.—Phil. Trans.* 1823. *Ann. of Phil.* xxiii. 89.

Supports combustion.—Some substances unite with chlorine with the evolution of light and heat, and hence it is called a supporter of combustion. In this respect, however, it differs considerably from oxygen gas. If a lighted taper be plunged into a vessel of chlorine gas, it burns for a short time with a small red flame, and emits a large quantity of smoke. Phosphorus takes fire in it spontaneously, and burns with a pale white light, if the temperature of the gas be raised to about 70° F. Several of the metals, such as tin, copper, arsenic, antimony and zinc, when introduced into chlorine in the state of powder, or of fine leaves, are suddenly inflamed. Great caution should be observed in performing these experiments to prevent the gas from being inhaled.

In all these cases of combustion in chlorine gas, the chlorine combines with the combustible, and there result a class of compounds named *Chlorides* or *Chlorurets.* These are sometimes acid and sometimes destitute of that property.

Has a strong attraction for hydrogen.—The following experiment affords a fine illustration of this fact. Dip a piece of thin gray paper folded like a match into oil of turpentine, allow any excess to drop off and then put it into a bottle of pure and dry chlorine, holding it with a pair of pincers. The oil of turpentine will immediately take fire and burn with a lurid flame, the chlorine combining with the hydrogen of the inflammable matter and precipitating carbon.

Discharges colours.—This assertion is correct when applied to chlo-

cloride, and of nitive opict forms a gas that burns catter

rine as it is usually obtained. But Sir H. Davy proved that chlorine, when perfectly dry, does not bleach. When combined with water, it possesses the property of bleaching in an eniment degree. This may be shown by introducing a solution of indigo or strips of calico into a solution of chlorine. In a short time the colours will be completely discharged, and they can never be restored. Hence an important practical application of chlorine, and some of its compounds, in the art of bleaching.

Is a powerful disinfecting agent.—The power of chlorine, for the purposes of fumigation, was shown by Guyton-Morveau, who ascertained that it destroyed the volatile principles given off by putrifying animal matters. It probably acts in a similar way on contagious effluvia. It is now extensively employed as a disinfecting agent, either in solution in water, or in the form of those peculiar compounds of chlorine and soda, and chlorine and lime, which have received the names of *Labarraque's disinfecting liquor*, and *Tennant's bleaching powder*, and which I shall notice hereafter.

It has been ascertained that the bleaching and disinfecting powers of chlorine are in exact proportion to each other, and it is probable that both these effects are produced in a similar way. During the process of bleaching, water is decomposed, in consequence of the great affinity between chlorine and hydrogen ; the decomposition of the colouring matter is occasioned by the oxygen which is liberated ; at the same time muriatic acid is always generated. The bleaching property of the deutoxide of hydrogen, of which oxygen is certainly the decolourizing principle, strengthens this view. The power of chlorine, as a disinfecting agent, depends also upon its great affinity for hydrogen, a substance entering largely into putrid affluvia, by means of which they are decomposed. This is illustrated in the cases of sulphuretted and carburetted hydrogen, which are in this way decomposed by chlorine, and rendered innoxious.

NATIVE STATE. Chlorine exists in nature in great abundance, but always combined with other bodies. Some of these compounds are very abundant, as muriatic acid, which is often thrown out in great quantities by volcanoes, and chloride of sodium which occurs in the form of rock salt, and also in solution in the waters in the sea, &c.

PREPARATION. Chlorine gas may be obtained,

1. By mixing concentrated muriatic acid, contained in a glass flask or retort, with half its weight of peroxide of manganese. Upon the application of heat the gas is freely evolved. It should be collected over warm water, in inverted glass bottles filled with the same liquid, and when the water is wholly displaced by the gas, the bottles should be closed with stoppers.

In this process a part of the muriatic acid is decomposed ; its hydrogen combines with one atom of the oxygen of the manganese, and forms water, while the chlorine is disengaged. At the same time also protoxide of manganese combines with an undecomposed portion of muriatic acid and forms muriate of the protoxide of manganese, which remains in the retort.

2. The more common and cheaper method of preparing chlorine, is to mix intimately three parts of common salt and one part of the peroxide of manganese, and to this mixture to add two parts of sulphuric acid, diluted with an equal weight of water.

In this case, sulphuric acid acting upon the solution of common salt, disengages muriatic acid, which is decomposed by the peroxide of manganese in the manner just explained. The residuum consists of sulphate of manganese and sulphate of soda.

3. The process recommended by Dumas is to treat the peroxide of manganese by a mixture of sulphuric and muriatic acids. The sulphuric acid, water and peroxide are introduced into the retort, and the muriatic acid is to be afterwards added by portions at a time. The chlorine is immediately disengaged, and it is only necessary to apply a gentle heat to sustain the temperature occasioned by the mixture of the sulphuric and water. The chlorine is drier than in the preceding, and is disengaged before the mixture boils.

The annexed cut exhibits the arrangement of the apparatus for procuring this gas.
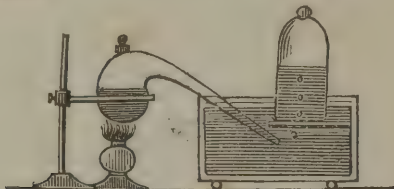
TESTS. Chlorine may in general be recognized by its colour and odour. Chemically, it may be detected by its bleaching property, and by the circumstance that a solution of the nitrate of silver, occasions in it a dense white precipitate (chloride of silver,) which becomes dark on exposure to light, is insoluble in acids, but completely soluble in pure ammonia.

ACTION ON THE ANIMAL ECONOMY. Chlorine in a gaseous state, destroys those who breathe it, by producing great irritation of the bronchia ; and even when diluted with atmospheric air, it causes cough and inflammation. Pelletier is thus said to have fallen a victim to its effects. [*Beck's Med. Juris.* 3d ed. 503.] The antidote in such cases is ammonia. In solution, however, chlorine is employed medicinally ; in some cases with great advantage. *See Ure's Chem. Dict.*

REFERENCES. *Scheele's Essays. Memoirs on the nature of Chlorine, by Davy, Van Mons, Thomson, Gay Lussac and Berzelius, Ann. of Phil. iii. iv. v. and vi. A comparison of the new and old theories of Chlorine, by Berzelius, Ann. of Phil. v. 7. Papers on the controversy concerning the nature of Chlorine, by Murray, Ure, Berthollet and Davy, Ann. of Phil. x. xi. xii. xiii. For a summary of this controversy up to 1818, see a note of Dr. T. Cooper, in the 1st volume of the American edition of Thomson's Chem. 155. Berzelius on the nature of Muriatic Acid, Ann. of Phil. ii. 254.*

CHLORINE AND OXYGEN.

These substances unite in four different proportions. The leading character of these compounds depends upon the fact, that chlorine and oxygen have a very feeble affinity for each other. They are therefore never met with in nature ; they can hence also be easily decomposed. These compounds are as follows :

	Cl.	O.
Protoxide of chlorine, - - - - -	35·45.....8.=43·45.
Peroxide of chlorine, - - - - -	35·45...32.=67·45.
Chloric acid, - - - - - - -	35·45...40.=75·45.
Perchloric acid, - - - - - - -	35·45...56.=91·45.

Protoxide of Chlorine*—*Atom. Num.* 43·45—*Symb.* O+Cl—*Sp. gr.*
2·417 air=1.

Discovered by Sir H. Davy in 1811, and described by him under the
name of *Euchlorine.*

PROPERTIES. Gaseous; colour yellowish-green, similar to that of
chlorine, but more brilliant; odour like that of burned sugar; bleach-
es vegetable substances, but gives the blue colours a red tint before
discharging them; is highly explosive; dissolves in water to eight or
ten times its volume; may be liquified by pressure.

Protoxide of Chlorine is highly explosive.—The heat of the hand, or
the pressure occasioned in transferring it from one vessel to another,
sometimes causes an explosion. This effect is also occasioned by phos-
phorus, which bursts into flame at the moment of immersion. All
burning bodies by their heat, occasion an explosion, and then burn
vividly in the decomposed gas. With hydrogen, it forms a mixture
which explodes by flame, or the electric spark, forming water and mu-
riatic acid. The best proportion is fifty measures of the protoxide of
chlorine to eighty of hydrogen.

PREPARATION. This gas is prepared by adding to two parts of chlo-
rate of potassa, one part of strong muriatic acid and one of water.
These ingredients should be put into a small retort, to which gentle
heat is to be applied. The gas must be collected over mercury. Prof.
Silliman recommends placing the materials in a small glass flask, fur-
nished with a tube bent twice at right angles, and passing to the bot-
tom of any clean dry phial, flask or tube, rather deep and with a nar-
row neck. A gentle heat, applied beneath the flask, soon disengages
the euchlorine gas, which, by its great weight, displaces the common
air from the recipient and takes its place. By using tongs properly
curved, so as to embrace the phials or tubes filled with the gas, the
operator may perform all the necessary experiments without danger of
causing an explosion by the warmth of the hands.—*Sill. Jour.* vi. 164.

REFERENCES. *Sir H. Davy, in Phil. Trans.* 1811. *Faraday, on the
liquefaction of Euchlorine, Phil. Trans.* 1823; *and Ann. of Phil.* xxiii.
95.

Peroxide of Chlorine—*Atom. Num.* 67·45—O+Cl—*Sp. gr.* 2·346
air = 1.

SYN. *Chlorous Acid.* Berzelius.—*Quadroxide of Chlorine.* Thom-
son.

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* The recent experiments of Mr. Soubeiran, have rendered the existence of
this gas doubtful; and the same author supports the opinion of Berzelius, that
the bleaching compounds contain a lower acid of chlorine, *Chlorous acid.*
But these views are not yet sufficiently settled to warrant the alterations, which
by their adoption, would become necessary.—*See Ann. de Chim.* xlviii., *or John-
ston's Report on Chemistry.*

Discovered by Sir H. Davy in 1815, and soon after by Count Stadion of Vienna.

PROPERTIES. Colour bright yellowish-green; odour aromatic, without any smell of chlorine; is rapidly absorbed by water; destroys most vegetable blues without previously reddening them; does not unite with alkalies; occasions the combustion and explosion of phosphorus when introduced into it; explodes violently when heated to a temperature of 212° F. emitting a strong light, and suffering a greater expansion than the protoxide of chlorine; it can be liquified by pressure.

PREPARATION. This substance is formed by the action of sulphuric acid upon chlorate of potassa. A quantity of this salt, not exceeding 50 or 60 grains, is reduced to powder and made into a paste by the addition of strong sulphuric acid. The mixture, which acquires a deep yellow colour, is placed in a glass retort, and heated by warm water, the temperature of which is kept under 212° F. The gas is to be collected over mercury.

The changes which take place in this process may be thus explained. The sulphuric acid decomposes some of the chlorate of potassa and liberates chloric acid. The chloric acid, at the moment of separation, resolves itself into peroxide of chlorine and oxygen; the last of which, instead of escaping as free oxygen gas, goes over to the acid of some undecomposed chlorate of potassa and converts it into perchloric acid. The whole products are bisulphate and perchlorate of potassa, and peroxide of chlorine.

One of the most striking properties of this gas, can be exhibited on a small scale, by adding to a few grains of chlorate of potassa in a test glass five or six drops of strong sulphuric acid. The gas is immediately disengaged. If a piece of cotton dipped in ether, be now brought into contact with the gas, it takes fire with a slight explosion. The cotton should be attached to a wire, and some care is necessary in performing the experiment.

REFERENCES. *Sir H. Davy, in Phil. Trans.* 1815. *Count Von Stadion, in Gilbert's Ann. der Phys.* lii. 179, *(Feb.* 1816.) *Berzelius, Trait. de Chim.* ii. 73, *where will be found the reasons for calling this an acid.*

Chloric Acid—Atom. Num, 75·45—*Symb.* 5O+Cl.

First obtained in a separate state by Gay Lussac.

PROPERTIES. Reddens vegetable blues; has a sour taste and forms neutral salts, called *Chlorates*, with alkaline and earthy bases; distinguished from chlorine by its not being possessed of bleaching properties; gives no precipitate with nitrate of silver, and can hence be distinguished from muriatic acid; is readily known by its forming a salt with potassa which, when thrown on burning charcoal, deflagrates like nitre.

PREPARATION. This acid may be obtained by adding to the chlorate of baryta a quantity of weak sulphuric acid, exactly sufficient for combining with the baryta. The insoluble sulphate subsides and pure chloric acid remains in the liquid. This may be concentrated by gentle heat, till it acquires an oily consistence.

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REFERENCES.　*Gay Lussac, in a memoir on Iodine, &c .Ann. of Phil.* vi. 129.

Perchloric Acid—Atom. Num. 91·45—*Symb.* 7O+Cl—*Sp. gr.* 1·65 water= 1.

PREPARATION.　The saline matter which remains in the retort after forming the peroxide of chlorine, is a mixture of perchlorate and bisulphate of potassa ; and by washing with cold water, the bisulphate is dissolved, and the perchlorate is left.　Perchloric acid may be prepared from this salt by mixing it in a retort with half its weight of sulphuric acid, diluted with one third of water, and applying heat to the mixture.　At the temperature of about 284° F. white vapours rise which condense as a colourless liquid in the receiver.　This is a solution of perchloric acid.　It has an acid taste, and reddens litmus paper without discharging its colour, and uniting with alkalies, forms *Perchlorates.*

REFERENCES.　*Stadion, in Gilbert's Ann. der Phys.* lii. 213.　*Berzelius, Trait de Chim.* ii. 65.

SECTION III.

BROMINE.

Atom. Num. 78·26—*Symb.* Br.—*Sp. gr.* 2·966 water =1.

Discovered by M. Balard of Montpelier, in 1826, and described by him under the name of *Muride.*　This has since been changed to *Bromine,* from the Greek *bromos,* in allusion to its strong odour.

PROPERTIES.　A liquid of a deep reddish-brown colour ; odour disagreeable, somewhat resembling that of chlorine ; taste powerful ; at common temperatures it emits red coloured vapours, which are very similar in appearance to those of nitrous acid ; and at 116·5° F. it enters into ebullition ; between the temperature of zero and—4° F. it is congealed, and in that state is brittle, but if combined with water so as to form a hydrate, it affords fine red crystals at 32° ; soluble in water, alcohol and ether, the latter being the best solvent ; does not redden litmus paper, but bleaches it rapidly like chlorine ; supports combustion ; acts with energy upon animal textures, giving the skin a yellow stain, and being highly destructive to life.

Bromine is volatile.—This can be shown by introducing a few drops of the liquid into a matrass ; the beautiful red vapour will soon fill the vessel.

Supports combustion.—Antimony and tin, take fire, and potassium causes a violent detonation, when brought into contact with bromine. Its vapour extinguishes a lighted taper, but before going out it burns for a short time with a flame surrounded by a greenish margin topped with red.—The compounds formed by the union of combustibles with bromine, are called *Bromides* or *Bromurets.*

NATIVE STATE.　This substance exists in sea water, in the form of hydrobromic acid, in combination probably with magnesia.　In this state it apparently forms an essential ingredient in ocean water ; for

it has been detected in the waters of the Mediterranean, Baltic, North Sea, and Frith of Forth. It has also been found in the waters of the Dead Sea, and in many brine springs in Germany, and in our own country. Finally, it has been detected in the ashes of certain sea weeds, and of some animals, as those of the *Janthina violacea.*

PREPARATION. Bromine is obtained by transmitting a current of chlorine gas through the bittern of sea water, and then agitating a portion of sulphuric ether with the liquid. The ether dissolves the whole of the bromine, from which it receives a beautiful hyacinth red tint, and on standing, rises to the surface. When the ethereal solution is agitated with caustic potassa, its colour entirely disappears, owing to the formation of hydrobromate and bromate of potassa, and the former salt is obtained in cubic crystals by evaporation. The bromine may then be set free by means of chlorine, and separated by heat.

TESTS. In most cases bromine is easily detected by means of chlorine ; for this substance displaces bromine from its combination with hydrogen, metals and most other bodies. The appearance of its vapour, or the colour of its solution in ether, will then render its presence obvious. Bromine also renders a solution of starch of an orange colour.

REFERENCES. *Balard on a peculiar substance contained in Sea Water, Ann. de Chim. et de Phys.* xxxii. 337, *and in Ann. of Phil.* xii. 381, 411—*contains also a notice of its compounds. Phil. Mag. and Ann.* vii. 234. viii. 225. *For a summary of what was known concerning Bromine and its compounds up to* 1828, *see New-York Med. and Phys. Jour.* vii. 141. *On the presence of Bromine in American saline waters, Silliman's Jour.* xviii. 142.

BROMINE AND OXYGEN.

Only one compound of bromine and oxygen has been hitherto discovered, which is bromic acid, similar in its constitution to chloric acid.

Bromic Acid—Atom. Num. 118·26—*Symb.* 5O+Br.

PROPERTIES. Odour scarcely any ; taste very acid, though not at all corrosive ; reddens litmus paper powerfully at first, and soon after destroys its colour ; is not affected by nitric or sulphuric acid, except when the latter is highly concentrated, in which case bromine is set free, and effervesence, probably owing to the escape of oxygen gas ensues ; unites with bases and forms a class of bodies termed *Bromates,* analogous to the chlorates.

PREPARATION. This acid may be procured in a separate state by decomposing a dilute solution of bromate of baryta, with sulphuric acid, so as to precipitate the whole of the baryta. The resulting solution of bromic acid may be concentrated by slow evaporation, until it acquires the consistence of syrup ; but on raising the temperature, in order to expel all the water, one part of the acid is volatilized, and the other resolved into oxygen and bromine. The same effect takes place when the evaporation is conducted *in vacuo,* with sulphuric acid ; and hence all attempts to obtain anhydrous bromic acid have been unsuccessful.

BROMINE AND CHLORINE.

We are acquainted with one compound of these elements, probably composed of one atom of each.

Chloride of Bromine.

Syn. *Chlorure Bromique.* Berzelius.

PROPERTIES. A volatile fluid, of a reddish-yellow colour, much less intense than that of bromine ; odour penetrating ; taste very disagreeable ; vapour of a deep yellow, like that of the oxides of chlorine ; soluble in water, in which state it possesses the colour, odour and bleaching properties of the compound.

PREPARATION. This compound may be formed at common temperatures, by transmitting a current of chlorine through bromine, and condensing the disengaged vapours by means of a freezing mixture.

SECTION IV.

IODINE.

Atom. Num. 126—*Symb.* I—*Sp. gr.* 4·948 water= 1.

Discovered in 1812, by M. Courtois, a manufacturer of saltpetre, at Paris ; recognized as a new body, by M. Clement, in 1813, and afterwards shown to be an elementary one, by Gay Lussac and Davy. The name is derived from the Greek *iodeez*, in allusion to the violet colour of its vapour.

PROPERTIES. A soft and friable solid, of a bluish-black colour, and metallic lustre ; a non-conductor of electricity ; produces a yellow stain upon the skin ; smell resembling that of diluted chlorine ; taste acrid ; is extremely volatile, rising into a rich violet coloured vapour, at a temperature of between 80° and 100° F.; fuses at 225° F., and enters into ebullition at 347° F.; is sparingly soluble in water but readily so in alcohol or ether ; acts energetically upon the animal system ; destroys vegetable colours, but forms a blue compound with starch ; combines with phosphorus and various other substances.

Iodine is very volatile.—This can be very easily shown by introducing into a retort or bolt head, a small portion of iodine, and applying a gentle heat. The violet vapours rise and fill the vessel : upon the application of cold these are again condensed.

Is sparingly soluble in water.— Water does not hold more than 1-7000ths of its weight of iodine in solution; but even this communicates a brownish tint. This tint disappears however when the water is exposed to the atmosphere. The proper solvents are ether and alcohol. It is in these forms that it is often employed for medicinal purposes.

Combines with phosphorus.—Phosphorus brought into contact with iodine takes fire, if the experiment is performed in the open air ; but in close vessels no light appears. Iodine combines, also, with most of the other non-metallic combustibles, and with the metals, forming a class of compounds denominated *Iodides* or *Iodurets*.

Forms a blue compound with starch.—This is a most delicate test for the presence of iodine, and it is said by Prof. Stromeyer, that a liquid containing 1-450,000 of its weight of iodine, receives a blue colour from starch. Two precautions should be observed to ensure success. First, the iodine must be in a free state, for it is the iodine alone and not any of its compounds which unites with starch. Secondly, the solution should be quite cold at the time of adding the starch ; for boiling water decomposes the blue compound and consequently removes its colour.

Crystallization of Iodine.—A large and beautiful crystallization may be obtained by saturating hot alcohol with a large proportion of iodine, and allowing the solution to cool gradually.—*Ingliss.*

NATIVE STATE. Iodine has been discovered in a great number of the fuci, which grow upon the sea shores, in sponges, in various molluscous animals, and in sea water ; and it has been found by Vauquelin, combined with silver, in South America. It has also been found, in a state of combination, in various salt springs in Europe and America.

PREPARATION. Lixiviate powdered *kelp,* (the semi-fused ashes of sea weed,) with cold water. Evaporate the lixivium till a pellicle forms, and then set it down to crystallize. Evaporate the mother liquor to dryness, and pour upon the mass half its weight of sulphuric acid. Apply heat to this mixture in an alembic to which a receiver is attached ; fumes of a violet colour arise and condense in the form of opaque crystals, having a metallic lustre, which are to be washed out of the head of the alembic with a small quantity of water and quickly dried upon bibulous paper.

ADULTERATION. Iodine is sometimes adulterated with black lead. This may be detected by dissolving the substance in alcohol, and also by subjecting it to heat. Black lead is not soluble in alcohol, neither is it vaporized by heat.

ACTION ON THE ANIMAL ECONOMY. In small doses iodine is employed with success in various diseases, but in larger ones it excites nausea and vomiting, and other distressing symptoms.—See *Magendie's Formulary, and Beck's Med. Juris.*

REFERENCES. *Gay Lussac, Ann of Phil.* iii. 106. *Van Mons. ibid.* 429. *Sir H. Davy, Phil. Trans.* 1814, *and Ann. of Phil.* iii. *and* iv. *Gay Lussac's Memoir on Iodine and its compounds, Ann. de Chim.* xci. 5, *and in Ann. of Phil.* v. 101, 207, 296, 401, vi. 124, 183. *Crystalline form of Iodine, Brande's Jour.* v. 364, *and Sill. Jour.* xviii. 84. *Hobson's Prize Essay on Iodine. Facts concerning Iodine from a prize essay by James Ingliss M. D., Lond. and Edin. Phil. Mag.* vii.

IODINE AND OXYGEN.

Two compounds of iodine and oxygen have been noticed by chemists —the *Iodous and Iodic Acids.* The former, however, as we shall presently see, is involved in some obscurity.

Iodous Acid.

Discovered by Prof. Sementini, of Naples, in 1824.

PROPERTIES. An oily liquid, having a disagreeable odour ; taste, acid, and astringent ; reddens vegetable blues permanently, without

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destroying them; is rapidly volatilized at 212° F. and evaporates slowly at common temperatures; is decomposed by sulphur; phosphorus and potassium take fire as soon as they come into contact with it.

PREPARATION. Equal parts of iodine and chlorate of potassa are to be triturated together in a glass or porcelain mortar, until they form a fine pulverulent yellow mass, in which the metallic lustre of the iodine is no longer visible. The mixture is then heated in a glass retort, and as soon as the chlorate begins to lose oxgen, iodous acid rises in the form of a dense white vapour, and condenses in the neck of the retort into a yellow liquid, which falls in drops into the receiver.

It is asserted by M. Wöhler that this compound does not consist of iodine and oxygen, but of chlorine and iodine. This has led to new investigations on the part of Sementini, which render it probable that there exists both iodous acid and oxide of iodine.—*Brande's Jour. N. S.* ii. 203.

REFERENCES. *Sementini's account, see Brande's Jour.* xvii. 381—*same work, N. S.* i. 477.

Iodic Acid—Atom. Num. 166— *Symb.* 5O+I.

Discovered about the same time by Gay Lussac and Sir H. Davy; by the latter of whom it was termed *Oxiodine*. In its dry state, it constitutes *Anhydrous Iodic Acid.*

PROPERTIES. A regular crystalline body which has a strong astringent sour taste, but no odour; density greater than that of sulphuric acid; is fused at 500° F. and resolved into oxygen and iodine; is very soluble in water, and deliquesces in moist air. The liquid acid thus formed, reddens vegetable blue colours, and afterwards destroys them. On evaporating the solution, a thick mass, of the consistence of paste, is left, which is *Hydrous Iodic Acid*, and from which, by the cautious application of heat, the water may be expelled. It acts powerfully on inflammable substances; with charcoal, sulphur, sugar and similar combustibles, forms mixtures which detonate when heated; combines with bases and forms a class of bodies denominated *Iodates*, which are analogous to the chlorates.

According to Mr. Connel this acid may be formed by digesting iodine with nitric acid over a spirit lamp, in a large flask, and washing down the iodine as it condenses on the sides of the flask.—[*Jameson's Jour.* 1831, p. 72.] The process recommended by Liebig is to precipitate the iodate of soda by chloride of barium; to every nine parts of the precipitate, well washed and dried, to add two of sulphuric acid diluted with ten or twelve of water, to boil half an hour, filter, evaporate to a sirupy consistence, and expose it to the air for several days. Regular transparent crystals are formed to the last drop.—*Johnston's Report on Chemistry.*

IODINE AND CHLORINE.

Chloriodic Acid—Atom. Num. 196·90—*Symb.* 2Cl+1.

Discovered by Gay Lussac and Sir H. Davy; and by the former called *Chloride of Iodine.*

PROPERTIES. A solid compound, of an orange yellow colour, when the iodine is fully saturated with chlorine, but of a reddish orange if

the iodine is in excess; by heat is converted into an orange liquid, which yields a vapour of the same tint on increase of temperature ; deliquesces in the open air and dissolves freely in water ; forms a colourless solution, which is very sour to the taste, and reddens vegetable blues, but afterwards destroys them.

Possesses acid properties.—On this point there is still some dispute. Davy gave the compound the name of chloriodic acid, but Gay Lussac on the contrary, conceives that the acidity of its solution arises from the presence of muriatic and iodic acids, which he supposes to be generated by the decomposition of water. The opinion of Davy is most generally received, yet this compound does not unite with alkaline substances, a fact somewhat difficult of explanation upon this supposition.

PREPARATION. This compound may be prepared very readily by the direct union of chlorine and iodine. It should be remarked that there are now supposed to be two or three compounds of chlorine and iodine.

IODINE AND BROMINE.

Bromides of Iodine.

Bromine and iodine act readily on each other and appear capable of uniting in two proportions. The proto-bromide is a solid, convertible by heat into a reddish-brown vapour, which in cooling, condenses into crystals of the same colour, and of a form resembling that of fern leaves. An additional quantity of bromine converts these crystals into a fluid, which, in appearance, is like a strong solution of iodine and hydriodic acid. This compound dissolves, without decomposition, in water, but with the alkalies yields hydrobromic and iodic acids. But, as is remarked by Dr. Turner, the existence of two bromides of iodine can scarcely be regarded as satisfactorily established.

SECTION V.

FLUORINE.

Atom. Num. 18·68. Symb. F.

The substance to which this name is applied has not heretofore been obtained in a separate state, and hence the properties which are peculiar to it in that state, are entirely unknown.* From the nature of its compounds it appears to belong to the class of supporters of combustion, and like oxygen and chlorine, to have a powerful affin-

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* M. Baudrimont, however, states that he has succeeded in separating fluorine by treating a mixture of fluoride of calcium and deutoxide of manganese, with sulphuric acid, in a glass tube. The gas thus obtained is mixed with the vapour of hydrofluoric acid and fluosilicic acid. This mixture, however, does not interfere with the observation of the principal properties of fluorine ; which is a gas of a yellowish brown colour, and possessing an odour resembling chlorine and burnt sugar. It bleaches indigo, does not act on glass, but combines directly with gold.—*L'Institut* 27th, April 1836, *quoted in Lond. and Edin. Phil. Mag.* ix. 149. *See also a paper by Mess. Knox in the same volume of the latter work.*

ity for hydrogen and metallic substances. With hydrogen it consti-
tutes a very peculiar acid, the *Hydrofluoric Acid*, which I shall notice
hereafter.

CHAPTER VII.

NON-METALLIC COMBUSTIBLES, OR ELECTRO-POSITIVE BODIES.

The substances included under this head are, HYDROGEN, NITROGEN,
SULPHUR, PHOSPHORUS, CARBON, BORON, and SELENIUM. These, togeth-
er with the compounds which they form with the bodies that precede
them, will now be described.

SECTION I.

HYDROGEN.

Atom. Num. 1—*Symb.* H—*Sp. gr.* 0·0694 air= 1.

First proved to be a distinct gas by Cavendish, in 1766. It derives its
name from the Greek words signifying the generator of water. It is
also sometimes called *Inflammable Air.*

PROPERTIES. A colourless gas, having neither odour nor taste, when
perfectly pure; a powerful refractor of light; the lightest body in na-
ture; is sparingly absorbed by water; inflammable in an eminent de-
gree; cannot support respiration or combustion; detonates when
combined with oxygen and fired; takes fire when brought into contact
with a platinum sponge; produces an intense degree of heat when
burned under pressure.

Hydrogen gas is destitute of odour.—This is only true of the most
pure form of this substance; but as commonly obtained, it has a slight-
ly disagreeable smell. This is owing to the presence of an oily mat-
ter which can be removed by passing the gas through a solution of
caustic potash.

Is the lightest body in nature.—100 cubic inches of this gas weigh
2·118 grains at mean pressure and temperature; it is 16 times lighter
than oxygen gas; 200,000 times lighter than mercury, and 300,000
times lighter than platinum.

The extreme levity of hydrogen can be shown by filling soap bub-
bles with it, which will be found to ascend rapidly. Hence balloons
are now filled with this gas.

Is highly inflammable.—The inflammability of hydrogen can be
shown in various ways.

A candle kindles a jar of it, but is itself extinguished by immersion
into the gas, and is relighted if the wick again touch the flame.

To a bottle containing the materials for hydrogen gas attach a tube.
If the common air be now allowed to escape, and the gas kindled at
the orifice of the tube, the jet is called the philosophic candle.

When a stream of hydrogen gas is burned under a tube of from 12

to 20 inches long, musical sounds are produced, owing to the succession of explosions which takes place.—*Faraday in Brande's Jour.* v. 274.

Hydrogen gas, when combined in the proportion of 2 parts to 1 part of oxygen, explodes violently on contact with the flame of a candle. The same thing takes place, though in an inferior degree, if the hydrogen be mixed with atmospheric air, in the proportion of 1 of hydrogen to about 3 of air. In each of these cases the product of combustion is water. These experiments may be performed in a strong glass vial or metallic air pistol, and the explosion is equally produced by the electric spark as by the contact of flame, or by a solid body heated to bright redness.

It has been discovered by M. Biot that a mixture of hydrogen and oxygen gases may be made to explode by mechanical compression. A mixture of these two gases, was introduced into a strong metallic syringe, furnished with a glass bottom, and a sudden stroke given to the piston; an extremely brilliant light appeared, accompanied with a loud detonation, and the glass bottom was forcibly driven out. The repetition of this experiment, it is obvious, must be attended with some difficulty and danger.—*Nicholson's Jour.* 8vo. xii. 212. *Henry's Chem.* i. 262.

Does not support combustion or respiration.—The former of these has already been shown, under the last article. An animal soon perishes, when confined in it. Death ensues from deprivation of oxygen, rather than from any noxious quality of the hydrogen, since an atmosphere composed of a due proportion of oxygen and hydrogen gases may be respired without inconvenience. It appears, however, according to the trials of Mess. Allen and Pepys, to have the curious property of throwing the animal into a profound sleep.

Takes fire when brought into contact with spongy platinum.—This singular fact was discovered by Professor Dobereiner of Jena, in 1824. For the purpose of exhibiting this experiment, let platinum sponge be prepared, by dissolving platinum in nitromuriatic acid, and then precipitating it by means of ammonia. If a jet of hydrogen from some orifice, and under high pressure, be brought into contact with this sponge, it instantly becomes red hot, and the gas soon takes fire. This has been applied in various ways to the construction of lamps for producing instantaneous light. Several metallic bodies produce the same effect; especially palladium, rhodium and iridium.

Produces an intense degree of heat, when burned under pressure.—Iron wire can readily be burned by a stream of hydrogen gas, under strong pressure.

But the most intense degree of heat is occasioned by the combustion of a mixture of hydrogen and oxygen gases, as it issues from a very small jet. This apparatus, commonly known as the *Compound* or *Oxyhydrogen blowpipe*, and first employed by Dr. Hare of Philadelphia, has been variously modified by Dr. Clarke, Mr. Newman, Dr. Wollaston, and others. These modifications were all proposed for the purpose of preventing the recession of the flame and the consequent explosion of the mixed gases: an object which has been most happily attained by the safety tube lately proposed by Mr. Hemming. It consists of a brass cylinder about six inches long and three fourth of an inch in diameter, filled with very fine brass wire, in length equal to that of the tube. A metallic rod 1-8th of an inch thick is then forcibly

driven through the centre of the bundle of wires in the tube, so as to wedge them firmly together. The interstices between the wires thus constitute very fine metallic tubes, the cooling and conducting powers of which are so great as entirely to intercept the passage of flame. So completely effectual is this contrivance that the wells and reservoirs ordinarily employed may be dispended with and the mixed gases supplied from a common bladder under the arm.—*Reports of the British Association for* 1832.

A very intense heat, quite sufficient for most purposes, may be safely and easily procured by causing a jet of oxygen gas to pass through the flame of a spirit lamp as proposed by Mr. Marcet. [*Ann. of Phil.* ii. 99.] Or still better, by substituting the flame of coal gas for that of alcohol, upon the plan of Mr. Daniell.—*Phil. Mag. & Jour. of Science,* 1833.

In all the above cases of combustion the product is water, and the heat produced can be accounted for upon the general principles which have been laid down, viz. that these gaseous substances, in assuming the liquid form, give out the caloric with which they are combined.

PREPARATION. Hydrogen gas may be easily procured in two ways.

1. By passing the vapour of water over metallic iron heated to redness. This is done by putting iron wire into a gun barrel B, open at both ends, to one of which is attached a retort A, containing pure
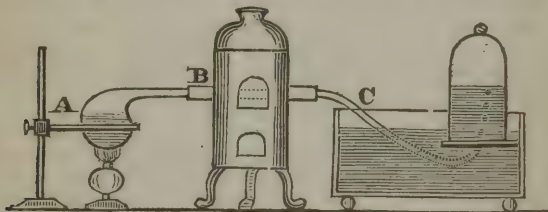
water, and to the other a bent tube C. The gun barrel is placed in a furnace, and when it has acquired a full red heat, the water in the retort is made to boil briskly. The gas, which is copiously disengaged as soon as the steam comes in contact with the glowing iron, passes along the bent tube, and may be collected in convenient vessels, by dipping the free extremity of the tube into the water of a pneumatic trough.

2. By putting pieces of iron or zinc into dilute sulphuric acid, formed of one part of strong acid to four or five of water—five are generally preferred. But in neither of these cases is the hydrogen absolutely pure; it has an offensive odour, derived from impurities in the iron and zinc, as they are met with in commerce. All these impurities, except carburetted hydrogen, may be removed by passing the gas through a solution of pure potassa. If hydrogen of great purity is desired, distilled zinc should be employed.

In both of the above cases water is decomposed; the oxygen combines with the metal and forms an oxide, and the hydrogen escapes in a gaseous form.

USES. Hydrogen is one of the constituents of water, combines with

a great number of bodies, and is found in almost all animal and vegetable substances.

REFERENCES. *Cavendish, experiments on Factitious Air, Phil. Trans.* 1766. *Action of Hydrogen upon Platinum, &c. Thenard, Traité de Chim.* i. 338. *An elaborate account of Dr. Clark's Compound Blow-pipe, and of its effects upon numerous refractory substances, is given in the appendix to the Life of Dr. Ed. D. Clarke. For papers on Dr. Hare's Blow-pipe, see Silliman's Jour.* i. 98. ii. 181, 281. *For directions concerning the making and filling of balloons, see Dumas, Chimie appliquée aux Arts.*

HYDROGEN AND OXYGEN.

Two compounds of these bodies are at present known, viz. *the Protoxide,* or *Water* and the *Deutoxide.*

Protoxide of Hydrogen or Water.

Atom. Num. 9—Symb. O+H— Sp. gr. 1.

PROPERTIES. A well known liquid, transparent, colourless, inodorous and tasteless ; compressible, by very strong pressure ; elastic ; a bad conductor of electricity, and changed by the application of heat into vapour, by the abstraction of it into ice. Its specific gravity is 1, the density of all solid and liquid bodies being referred to it as a term of comparison. One cubic inch, at 60° F. and 30 Bar. weighs 252·525 grains, so that it is 828 times heavier than atmospheric air.

The following are among the most important chemical properties of water.

1. *It contains air.*—This may be shown by placing a glass vessel of water, fresh from a spring, or even of distilled water that has been exposed a few days to the atmosphere, under the receiver of an air pump. During the exhaustion of the receiver, bubbles of air will be seen to ascend very plentifully. Much air escapes also from water during boiling, and may be collected by a proper apparatus ; but it again absorbs it when exposed to the atmosphere.

Water which has been deprived of its air, by long boiling, possesses the property of absorbing every gas, though the quantity which it is capable of absorbing varies considerably with respect to the different gases.

Water absorbs, at the mean pressure and temperature, according to the investigations of Henry and Dalton.

Of carbonic acid gas, ...	its own bulk.
Sulphuretted hydrogen, ...	do.
Nitrous oxide, ...	do.
Olefiant gas, ...	1-8th.
Oxygen gas, ...	1-27th.
Nitrous gas, ...	do.
Carburetted hydrogen, ...	do.
Carbonic oxide, ...	1-64th.
Nitrogen gas, ...	do.
Hydrogen gas, ...	do.

[*Henry,* i. 276, *Ann. of Phil.* vi. 340, vii. 215.]

2. *It enters into combination with various bodies.*—Sometimes it is contained in a variable ratio, as in solution ; at others it forms a mere accidental ingredient, as in common salt or sulphate of potassa. In many instances, however, it unites in a fixed definite proportion ; as is the case in its combination with several of the acids, and metallic oxides and of all the salts that contain water of crystallization. These compounds are termed *Hydrates ;* and in some of them the water is held by so powerful an affinity as not to be separated by a very high temperature. The pure alkalies potassa and soda, retain, for example, even after fusion, about one-fifth their weight of water, of which they can only be deprived by some body having a stronger affinity for the alkali.

Water is contained in the atmosphere, even during the driest weather. —Expose to the air, in a shallow vessel, a little subcarbonate of potassa, or common salt of tartar ; in a few days it will have become moist, or deliquiated, and will have increased considerably in weight. So also when sulphuric acid is added to common salt, dense white fumes are given out, in consequence of the combination of the muriatic acid with the moisture in the air.

There are two different theories of the state in which water exists in the atmosphere, and in other gases. By most chemists it has been considered as united to air by chemical affinity, and when abstracted by other bodies, the effect has been ascribed to the superior affinity of those bodies for water. According to Mr. Dalton, however, aqueous vapour constitutes a distinct and independent atmosphere, the elastic force of which forms, at different temperatures, different proportions of the elastic force of the whole ; for example, at the temperature of 65° F. it gives to air 1-50th of its elasticity. Hence, a volume of air or gas at any temperature, saturated with moisture, contains as much steam as would exist, at that temperature, in a vacuum of equal capacity. This view, confirmed by the experiments of Gay Lussac, is much more probable than that which explains the phenomena by chemical affinity ; and it is supported especially by the fact that the absorption of caloric is precisely the same in amount in spontaneous as in forced evaporation. It steers clear also of the inconsistency attending the supposition that the vapour contained in the atmosphere, at ordinary temperatures, is in a different state from that existing in a Toricellian vacuum ; and again, that water below 212° F. is chemically combined with the atmosphere, and above 212° assumes a new form and becomes a distinct elastic fluid, called *steam*. It is certainly much more reasonable to suppose that water, whenever it exists as an elastic fluid, whether distinct from, or mixed with others, is maintained as such by one and the same cause, viz. *by its constituent caloric*, and not by chemical solution, in any gas or mixture of gases.—*Henry*, i. 278.

The purest water that can be found as a natural product, is produced by melting freshly fallen snow, or by receiving rain in clean vessels at a distance from houses. But this water is not absolutely pure ; for if placed under the exhausted receiver of an air-pump, or boiled briskly for a few minutes, bubbles of gas escape from it. The air obtained in this way from snow water, is much richer in oxygen gas than atmospheric air. According to the experiments of Gay Lussac and Humboldt, it contains 34·8 per cent of oxygen, and the air separated by ebullition from rain-water contains 32 per cent of that gas. All water which has once fallen on the ground, becomes impregnated with more or less

of earthy or saline matters, and it can be separated from them only by distillation. The distilled water thus obtained, and preserved in clean well stopped vessels, is absolutely pure. In this state it is employed for the purpose of analysis and in pharmacy.

The process of distillation is shown in the accompanying cut, in which A is a retort containing water and heated by a lamp, B the receiver to which the retort is attached and which is kept cold by the dropping of water through a funnel containing a filler.
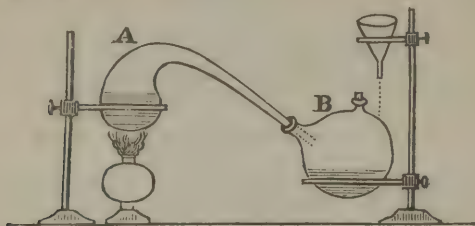
Ice. When water is exposed to the action of cold, it condenses more and more, until it reaches the temperature of about 39° F.; after which it expands to the point of congelation. Hence ice is lighter than water: its specific gravity is not far from 0·93.—[*See page* 48.]

Ice exists naturally at the poles, even in the midst of the sea, at all times. Under other parallels it is found in this state only at a certain elevation, which increases as we proceed from the poles to the equator. The masses of snow which accumulate on the summits of mountains, being alternately melted and congealed, become at last changed by this process into solid ice, often grouped and fashioned by such irregular action into the most fantastic shapes, constituting what are denominated *Glaciers.* In its native seat, this icy belt acquires continual additions to its height, till the accumulating pressure at last tears the mass from its base and precipitates its dissevered fragments to a lower level. In its new position, below the inferior boundary of congelation the enormous pile suffers, on the whole, a very gradual thaw, which is sometimes protracted for several centuries, and gives birth to streams of greater or less magnitude. Meanwhile in the higher magazine, another icy belt is again slowly collecting, which will in due time repeat the succession, and maintain the eternal circle of production and decay. —*See Art. Climate, in Suppl. Encycl. Brit.*

Vapour or steam.—If water be exposed to the heat of 212°, the barometer being 30, it is converted into a transparent gas, which is called *aqueous vapour* or *steam,* the bulk of which is about 1700 times greater than that of water. Under a diminished pressure, however, water boils below the temperature of 212°, while on the contrary, when the pressure is increased, the boiling point is higher. In every case, therefore, the tension of the vapour depends upon the temperature. A table has been constructed by Mr. Dalton to show the elastic force of vapour at every degree of the thermometer.

The boiling of water is influenced in some degree also by its purity. Thus, if it contains a portion of common salt in solution, its specific gravity will be increased, and under the same pressure the boiling point will be several degrees higher than when the water is pure.

11

Composition of water. This may be determined by *analysis* and *syn-thesis.* 1st, by Synthesis.

When two volumes of hydrogen are mixed with one volume of oxy-gen gas, and the mixture inflamed in a proper apparatus by the elec-tric spark, the gases totally disappear, and the interior of the vessel is covered with drops of pure water, equal in weight to that of the gases consumed. The same effect is also produced by burning hydrogen in an atmosphere of pure oxygen gas. An apparatus for producing water by the electric spark, is figured in the *Library of Useful Knowledge, art. Chemistry.*

It should be recollected that every gas is a compound of gravitating matter with heat, and perhaps electricity and light. In the above ex-periments the *bases* of these gases combine to form water, the impon-derable ingredients having for the most part escaped during the com-bustion.

2. The composition of water may be proved analytically as fol-lows:

By exposing pure water to the action of the voltaic battery, it is re-solved into two volumes of hydrogen, disengaged at the negative pole, and one volume of oxygen, disengaged at the positive ; and hence the atomic constitution is such as has been stated above. Water may also be resolved into its elements by passing its vapour over red hot iron, when the oxygen combines with the iron and the hydrogen is liberated in the gaseous form. (See page 118.)

REFERENCES. *Thenard's Chem.* ii. 2. *Berzelius's very elaborate ac-count, Trait. de Chim.* i. 397. *Parkes' Chemical Essays.*

Deutoxide or Peroxide of Hydrogen—Atom. Num. 17—*Symb.* 2O+H.—*Sp. gr.* 1.452 water= 1.

A singular compound discovered by M. Thenard, in 1818. Some-times also called *Oxygenized Water.*

PROPERTIES. A colourless transparent liquid, without odour ; it whitens the skin when applied to it, and even destroys its texture if the application be long continued ; possesses bleaching properties ; is slowly volatilized *in vacuo,* and hence its vapour is much less elastic than that of water ; it has not been congealed by any degree of cold hitherto applied to it.

The most remarkable property of the deutoxide of hydrogen is the facility with which it can be decomposed. A temperature of 59° F. is sufficient to decompose it and to liberate oxygen gas in great abun-dance. The action of heat varies with the degree of concentration. Seven or eight grains of the sp. gr. 1.452, when suddenly heated, are sufficient to occasion a violent explosion ; and therefore to obtain safe-ly the whole of its excess of oxygen above that constituting water, it is necessary before applying heat, to dilute it with about 20 parts by weight of water.

This substance is powerfully acted on by many of the metals and metallic oxides. Tin, iron, antimony, and tellurium bring it back ra-pidly to the state of water. Gold, platinum and silver, when finely divided and added to it, liberate its oxygen, without themselves un-dergoing any change. Arsenic, tungsten, potassium, &c. liberate one part of the oxygen and absorb the rest. It is also decomposed by several

of the metallic protoxides, as those of iron, tin, manganese, &c.; and the peroxides of silver, lead, mercury, gold, and some others act upon it with great energy, exciting an intense heat accompanied with a kind of explosion. On the contrary, the acids have the property of rendering it a more stable compound.

PREPARATION. To obtain this substance it is necessary to employ the *Peroxide of Barium*, a compound, which will be described under the article *Barium*. This compound, when acted upon by liquid muriatic acid, abandons part of its oxygen, and is reduced to the state of protoxide, which unites with the muriatic acid, while the oxygen unites with the water. Sulphuric acid, added to the compound fluid, carries down the baryta and sets muriatic acid at liberty, which is ready to act upon a fresh quantity of the peroxide of barium. This operation may be several times repeated, and at each repetition the water becomes charged with an additional quantity of oxygen. When the process has been carried far enough, sulphate of silver is added, to precipitate the free muriatic acid, which it replaces by a quantity of free sulphuric acid; but the latter is easily separated by adding a due proportion of baryta. This is a very general outline of the process, which requires for its success several precautions, and especially the greatest attention to the purity of the peroxide of barium. Minute directions are given by Thenard in the original paper.

REFERENCES. *Ann. de Chim. et de Ph.* viii. ix. *Ann. of Phil.* xiii. xiv. xv. *and Brande's Jour.* vi. 150, 379—viii. 114, 154. *Thenard* ii. 42. *Berzelius,* i. 451, *under the name of Sur-oxide hydrique.* *For Dr. Thomson's views concerning the action of the metals and metallic oxides upon the above compound, see his Inorganic Chemistry,* i. 43.

HYDROGEN AND CHLORINE.

Hydrochloric or Muriatic Acid—Atom. Num. 36·45— *Symb.* Cl+H— *Sp. gr.* 1·269 air=1.

Discovered by Priestley in 1772, and for a long time known under the names of *Spirit of Salt* and of *Marine Acid.*

PROPERTIES A colourless gas, of a pungent odour and acid taste; extinguishes burning bodies, and is quite irrespirable, exciting violent spasm of the glottis; produces a white cloud when brought into contact with common air, owing to its union with the aqueous vapour always present in the atmosphere; is decomposed by being mixed with oxygen and submitted to the action of electricity; rapidly absorbed by water, forming liquid muriatic acid, under a pressure of 40 atmospheres; at the temperature of 50° F. it is liquid; it combines with bases forming a class of salts called *Muriates* or *Hydrochlorates.*

It extinguishes a lighted taper.— Before the flame goes out, the upper part of it assumes a greenish hue, the cause of which has not yet been explained. A white vapour also surrounds the extinguished wick, owing to the combination of water, produced by the combustion of the candle, with the muriatic acid gas.

It is decomposed by electricity.—When muriatic acid gas is subjected to the action of a galvanic battery, it is readily decomposed, hydrogen appearing at the negative, and chlorine at the positive pole. It is also decomposed by ordinary electricity. The decomposition,

however, is incomplete; for though one electric spark resolves a portion of the gas into its elements, the next shock in a great measure effects their reunion. It is not affected by oxygen under common circumstances; but if a mixture of oxygen and muriatic acid gases is electrified the oxygen unites with the hydrogen of the muriatic acid to form water, and chlorine is set at liberty.—*Henry, Phil. Trans.* 1812 and 1824.

Some of the metals effect its partial decomposition.—Potassium, by being heated in muriatic acid gas, liberates one third of its volume of hydrogen. Heated zinc and tin disengage a volume of hydrogen equal to one half that of the muriatic acid gas, and chlorides of those metals are obtained.—*Davy, Phil. Trans.* 1810.

It is rapidly absorbed by water.—A drop or two of water admitted to a large jar full of muriatic acid gas, causes the whole instantly to disappear. And on opening a long wide jar filled with it, under water, the absorption of the gas takes place so instantaneously, that the water is forced up into the jar with the same violence as into a vacuum. When a piece of ice is put into a jar full of the gas, confined over mercury, the ice liquifies on the instant, and the whole of the gas disappears in the course of a few seconds.

NATIVE STATE. Muriatic acid is one of the gaseous substances which issue from the craters of volcanoes. It has also been found by Humboldt in a number of warm springs in Mexico.

PREPARATION. This may be effected in various ways.

1. If a phial be entirely filled with a mixture of chlorine and hydrogen gases in equal proportions, and a well ground stopper be introduced, no action takes place, provided light is carefully and completely excluded, even by standing some time; but, on applying a lighted taper, or on passing an electric spark through the mixture, the gases immediately explode.

2. Let a stout and well stopped phial, capable of holding three or four ounce measures, be filled over water with equal volumes of chlorine and hydrogen gases, and a ground stopper introduced. Expose it to the ordinary day light, guarding it from the direct rays of the sun, and in twelve or fourteen hours the colour of the chlorine will have disappeared; and on withdrawing the stopper under water, the phial will be immediately filled with that fluid.

3. If the experiment be repeated, with this difference that the phial is exposed to the direct rays of the sun, the combination will take place rapidly, and a detonation will ensue, which will probably drive out the stopper. But if this should not happen, the stopper may be removed under water, which will ascend and completely fill the bottle. Prof. Silliman however has related the accidental explosion of a mixture of these gases, in the quantity that filled a Florence flask, not only when no direct solar light fell upon it, but when the diffuse light of day was rendered more feeble than common by a thick snow storm. [*Amer. Jour.* iii. 342.] This fact serves as a caution against mixing the two gases in considerable quantities.

Mr. Brande found [*Phil. Trans.* 1820] that the intense light, issuing from charcoal points connected with a powerful galvanic battery, was as effectual as solar light in acting on hydrogen and chlorine gases and causing them to detonate; but he could not produce an analogous ef-

fect by any other terrestrial light. The moon's rays, also, he found to be quite inefficient on a mixture of these two gases.

To obtain muriatic acid in sufficient quantity for the exhibition of its properties, the direct combination of hydrogen and chlorine is not an eligible process. It may be procured more conveniently as follows;

1. By putting an ounce of strong liquid muriatic acid into a glass flask or retort, and heating it by means of a lamp till the liquid boils. Pure muriatic acid gas is freely evolved, and may be collected over mercury.

2. By adding concentrated sulphuric acid to an equal weight of common salt, in a tubulated retort or gas bottle. Brisk effervescence ensues at the moment of making the mixture, and on the application of heat a large quantity of muriatic acid gas is disengaged.

In the first process muriatic acid, previously dissolved in water, is simply expelled from the water by increased temperature. In the second, a portion of the water contained in the liquid sulphuric acid is resolved into its elements, the hydrogen unites with the chlorine of the common salt, forming muriatic acid, which escapes in the form of gas; while soda is generated by the combination of oxygen with the sodium, which combines with the sulphuric acid and forms sulphate of soda. The water contained in the liquid sulphuric acid is therefore essential to the success of the operation. The affinities which determine the change are the attraction of chlorine for hydrogen, of sodium for oxygen, and of soda for sulphuric acid.

Liquid muriatic acid.—The liquid muriatic acid may be obtained by passing a current of the gas into water so long as it is absorbed. A considerable increase of temperature takes place during the absorption, and therefore the apparatus should be kept cool by ice. Sir H. Davy states that water, at the temperature of 40° F. absorbs 480 times its volume of the gas, and that the solution has the density of 1·2109. According to Dr. Thomson one cubic inch of water, at the temperature of 69° F. is capable of absorbing 417·822 cubic inches of muriatic acid gas, and when cooled down to the temperature of the air, occupies the space of 1·3433 cubic inch. One cubic inch of this acid contains 311·041 cubic inches of muriatic acid gas, and it has a density of 1·1958 and contains 40·39 per cent. of real acid, united with 50·61 of water. In winter he has obtained muriatic acid of as high a specific gravity as 1·212.

Dr. Thomson has constructed a table which exhibits the specific gravity of this acid of determinate strength. His method of proceeding was to saturate a given weight of the acid with calcareous spar. Every 50 grains of spar, (or pure marble,) dissolved, indicated the presence of 37 grains of muriatic acid. Knowing the exact strength of one particular acid, it was easy, by the addition of determinate weights of water, to form acid of any inferior strength required.— *Thomson's First Princip.* i. 86, 87.

Directions for obtaining liquid muriatic acid are given in most of the Pharmacopeias. The process recommended by the Edinburgh college is very good. The proportions they prescribe are equal weights of common salt, water and sulphuric acid, more acid being purposely employed than is sufficient to form a neutral sulphate with the soda, so that the more perfect decomposition of the salt may be insured. To prevent too violent an action at first, the acid is mixed with one-third

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its weight of water, and when the mixture is cool, it is thrown into the vessel containing the salt. The heat of a sand bath or lamp is now applied and the distillation is continued to dryness. The gas that is formed passes into a receiver, which is luted to the retort, and contains about twice the quantity of water used in diluting the sulphuric acid. By this process muriatic acid may be obtained of the specific gravity of 1·170.

Liquid muriatic acid has the following properties:

1. It emits white suffocating fumes, consisting of muriatic acid gas, which becomes visible by contact with the moisture of the air.

2. When heated in a retort or glass bottle, muriatic acid gas is disengaged, and may be collected over mercury.

3. Liquid muriatic acid is not decomposed by the contact of charcoal, essential oils, or other combustible bodies.

4. When diluted with water, an elevation of temperature is produced, much less remarkable, however, than that occasioned by diluting sulphuric acid; and when the mixture has cooled to its former temperature, a diminution of volume is found to have ensued.

5. In a perfectly pure state, liquid muriatic acid is quite colourless; but it has frequently a yellowish hue. This may proceed either from a portion of chlorine or muriate of iron, but most commonly of the latter. This colour is instantly destroyed by a few drops of muriate of tin; but this addition, instead of diminishing, obviously increases the impurity of the acid.

Uses. Muriatic acid is used in large quantities in the preparation of muriate of tin. It is also used in several other arts, and is a valuable re-agent in the laboratory.

Views concerning the nature of Muriatic Acid.— The theoretical views concerning the nature of muriatic acid, have undergone many and important changes. Scheele considered it a compound of a certain base and an imaginary principle, called *phlogiston.* It was afterwards supposed to be a simple body, which, by its union with oxygen, formed oxymuriatic acid, now called chlorine. And this opinion prevailed until the experiments of Sir H. Davy, Gay Lussac and Thenard left no doubt that chlorine is an undecompounded substance, and that muriatic acid is a compound of chlorine and hydrogen. For the discussions on this subject the reader may consult the works and papers referred to under the article chlorine.

REFERENCES. *Gay Lussac and Thenard's Recherches, Phys. Chim.* vol. ii. *Davy's Elements of Chem. On the quantity of real Acid in Liquid Hydrochloric, by Dr. Ure, Ann. of Phil.* x. 268. *The chapter on Muriatic Acid, in Chaptal's Chem.* iii. 83. *For the methods of Manufacture, &c. see Gray's Operative Chemist,* 426 ; *and Dumas, Chimie appliquée aux Arts.*

HYDROGEN AND IODINE.

Hydriodic Acid—*Atom. Num.* 127—*Symb.* $1 + H$—*Sp. gr.* 4·4092 air $= 1$.

This acid was discovered by Gay Lussac, and to him and Davy we are indebted for a knowledge of most of its properties.

PROPERTIES. A colourless, transparent gas, of an acid taste and an odour similar to that of muriatic acid; reddens litmus powerfully; does not support combustion; is partly decomposed by a red heat, and completely when mixed with oxygen, forming water and separating the iodine; forms white fumes when admitted into the air, and is rapidly absorbed by water, resembling, in both these respects, muriatic acid; when brought into contact with chlorine it is decomposed, muriatic acid being formed, and the vessel is filled with the vapour of iodine; it is also decomposed by many of the metals, as potassium, sodium, zinc, iron, mercury, &c. at ordinary temperatures, the iodine combining with the metal, and the Hydrogen passing off.

NATIVE STATE. Hydriodic acid is found native in several species of Fucus, in sponges, &c. usually in combination with potassa or soda. Vauquelin has also detected it in combination with silver.

PREPARATION. This may be procured,

1. By passing a mixture of hydrogen gas and the vapour of iodine through a red hot porcelain tube.

2. It may also be obtained quite pure by the action of water on the iodide of phosphorus. For this purpose we introduce into a small retort some moistened iodine, and afterwards add to it one-eighth or one-twelfth its weight of phosphorus. An iodide of phosphorus is formed, which instantly reacts upon the water. Mutual decomposition ensues; the oxygen of the water unites with the phosphorus, and the hydrogen with the iodine, giving rise to the formation of phosphoric and hydriodic acids. On the application of a moderate heat the latter passes over in the form of a colourless gas, and is collected in receivers, filled with common air, which, by a proper management, it will expel by its superior specific gravity.

Liquid Hydriodic Acid, or the solution of hydriodic acid in water, is fuming, and when saturated has a density of 1·7. It does not act upon mercury, although in the gaseous state it attacks it powerfully. Chlorine takes the hydrogen from this compound; muriatic acid is formed and iodine is liberated. It is slowly decomposed by contact with air, the hydrogen being attracted by the oxygen of the atmosphere; it is also decomposed by galvanic electricity, by concentrated sulphuric and nitric acids, and by those oxides which hold their oxygen loosely. With other oxides it combines and forms a genus of neutral salts, called *Hydriodates*.

HYDROGEN AND BROMINE.

Hydrobromic Acid—Atom. Num 79·26—Symb. Br+H.

Discovered by M. Balard.

PROPERTIES. A colourless gas, with an intensely acid taste; by contact with atmospheric air gives white vapours, more dense than those produced by hydrochloric acid, under the same circumstances; it has a pungent irritating odour; is decomposed by chlorine, which instantly liberates abundant vapours, that condense into drops of bromine; decomposed at common temperatures by potassium, in which case a volume of hydrogen remains, exactly equivalent to half that of the original gas. And hence its composition is analagous to that of hydriodic and hydrochloric acids, being equal volumes of bromine and hydrogen without condensation. The salts of acids are termed *Hydrobromates*.

Hydrobromic acid is very soluble in water, which, by absorbing the gas, increases in volume, acquires great density, and also the property of emitting white vapours by contact with the air. This solution is colourless and possesses the principal properties of the gas.

PREPARATION. Hydrobromic acid is generated by exposing a mixture of hydrogen and bromine to the flame of a taper, or what is still better, by introducing an ignited iron rod into a bottle containing it. It may also be procured by a process analogous to that used for hydriodic acid gas. Bromine and phosphorus, placed in contact, and moistened with a few drops of water, afford abundantly a gas which is the acid in question.

HYDROGEN AND FLUORINE.

Hydrofluoric Acid—Atom. Num. 19·68—*Symb.* F+H.

The property which *Fluor* or *Derbyshire Spar* possesses of corroding glass when mixed with sulphuric acid, is said to have been known at Nuremberg as early as 1670. Scheele, in 1771, pointed out that the property of corroding glass was due to an acid given off by the action of sulphuric acid upon fluor spar. Gay Lussac and Thenard, however, first pointed out the method of obtaining the acid in a pure form.

PROPERTIES. Hydrofluoric acid at the temperature of 32° F. is a colourless fluid, remaining in that state at 59° F. if preserved in well stopped bottles; but when exposed to the air flies off in dense white fumes, which consist of the vapour of the acid in combination with the moisture of the air ; its specific gravity when first prepared is 1·06, but is increased, by the gradual addition of water, to 1·25, and there is no known instance of a similar condensation ; its vapours are highly irritating, and when applied to the skin it disorganizes it so rapidly as to occasion dangerous ulcers ; in addition to the usual properties of a powerful acid, it acts strongly on glass and corrodes it deeply ; it also dissolves some bodies which resist the action even of nitro-muriatic acid, as silicium, zirconium and columbium ; when brought into contact with potassium, violent detonation takes place, hydrogen gas escapes, and a white compound, *fluoride of potassium,* is generated ; with the alkalies it forms salts, called *Hydrofluates.*

Hydrofluoric acid corrodes glass.—When glass is brought into contact with this acid, its transparency is instantly destroyed. This effect is produced by the union of the acid with the silex of the glass, and the product is a colourless gas known by the name of *fluo-silicic acid.* It is in consequence of this affinity for siliceous matter that plates of glass, covered with a composition of beeswax and turpentine, and drawn upon with a graver, may have those parts which are laid bare etched by exposure either to the vapour or to the diluted acid.

PREPARATION. As glass is immediately corroded by this acid, we must employ vessels of lead or silver in procuring it. The following method is suggested by Gay Lussac. A retort of pure lead must be procured, composed of two pieces which slip into each other. To this retort must be adapted a leaden receiver. Take any quantity of pure fluor spar, reduce it to a fine powder, and put it into the retort, then mix it well with twice its weight of concentrated sulphuric acid. Lute the joining of the retort and the beak where it enters the receiver with clay, then apply a moderate heat to the retort, taking care that it is not so great as to fuse the lead. The receiver is to be surrounded with

a mixture of common salt and snow.   The acid is disengaged and collected in the receiver in a liquid state.

For the purpose of exhibiting the effects of the vapour upon glass, a small square or oblong leaden vessel will suffice.   Into this the fluor spar and sulphuric acid are to be put and gentle heat afterwards applied.

Attempts have been made to effect the decomposition or this acid, both upon the supposition that it may be a compound of an electropositive body, such as sulphur with oxygen, or that it is constituted of a highly electro negative element, like chlorine, in union with hydrogen. The latter view is, of the two, the best supported by experiment and analogy. A strong argument in its favour is derived from the fact discovered by Kuhlman, that fluor spar is not decomposed by the *anhydrous* sulphuric acid. [*Ann. de Chim. et de Phys. Feb.* 1827.] There being no water to furnish oxygen to the calcium, or hydrogen to the fluorine, the hydrofluoric acid cannot be produced. [See note on page 115].

REFERENCES.   *Puymaurin on the action of Fluoric Acid on silicious Earth, and engraving with it on Glass, Repert. of Arts. 1st. ser.* v. 210, 271. *Gay Lussac and Thenard on the Fluoric Acid. and its decomposition, Jour. de Phys. January,* 1809, *and Repert. of Arts,* 2d ser. xv. 90. *Davy's experiments on Fluoric Acid, Phil. Trans.* 1812, *and in Repert. of Arts,* 2d ser. xxii. 72. *Berzelius on Fluoric Acid and its most remarkable combinations, Ann. of Phil.* xxiv. *and* xxv.—*Also, Traité de Chim. by the same author.*

SECTION II.

NITROGEN.

Atom. Num. 14—*Symb.* N—*Sp. gr.* 0·9722 air = 1.

First noticed as a distinct gas by Dr. Rutherford, in 1772.   But first discovered as a constituent part of the atmosphere by Lavoisier, in 1775, who named it *Azote.* It has also been called *Mephitic Air,* but *Nitrogen* appears to be the most appropriate name.

PROPERTIES.   A gaseous body without colour, taste or odour ; does not support combustion nor animal life ; is not inflammable like hydrogen, though under favourable circumstances it may be made to unite with oxygen ; is very sparingly absorbed by water.

It extinguishes burning bodies.—This can be easily shown by immersing a lighted taper or candle into a vessel of nitrogen gas.

Does not support animal life.—Although no animal can live in an atmosphere of nitrogen, yet it exerts no injurious action either on the lungs or on the system at large, the privation of oxygen being the sole cause of death.   Indeed this gas is more distinguished by negative characters than any striking quality.

NATIVE STATE.   Nitrogen gas is sometimes given off by hot springs. Dr. Daubeny has found it in hot springs in Scotland, on the Alps and in France.   It is also evolved from the Lebanon springs in the state of New York.

PREPARATION.   Nitrogen gas may be obtained in several ways.

1. By burning a piece of phosphorus in a jar of air inverted over water. The strong affinity of phosphorus for oxygen, enables it to burn till the whole of that gas is consumed. The product of the combustion, pyrophosphoric acid, is at first diffused through the residue in the form of a white cloud; but is rapidly absorbed by water, and disappears in the course of half an hour. The residual gas is nitrogen, containing a small quantity of carbonic acid and vapour of phosphorus, both of which may be removed by agitating it briskly with a solution of pure potassa. This process is usually adopted.

2. By introducing a solution of proto-sulphate of iron, charged with the deutoxide of nitrogen, into a vessel of atmospheric air—the oxygen will be absorbed in a few minutes. A stick of phosphorus produces the same effects in 24 hours, if exposed to a temperature of 60° F. A solution of the sulphuret of potassa or of lime—or a paste made of equal parts of iron filings and sulphur, with water, acts in a similar manner.

3. By exposing a mixture of fresh muscle and nitric acid of specific gravity 1·20 to a moderate temperature, effervesence takes place and nitrogen is liberated, mixed however, with carbonic acid, which may be separated by lime water.

In all these processes, except the last, the theory of which is somewhat complex, some substance is brought into contact with atmospheric air which has a strong affinity for its oxygen, with which it forms a compound and leaves the nitrogen in a separate state.

Uses. Nitrogen is without use in the arts or in medicine. But it must perform some important office in the animal economy, since the only difference between animal and vegetable substances consists in the presence or absence of this principle.

Nature of Nitrogen. Though nitrogen is ranked among the simple non-metallic bodies, Berzelius, Davy and others have maintained the opinion that it is compound. But this view does not appear to be supported by experiment. Those who are desirous of examining the facts and reasonings in favour of this opinion, are referred to Berzelius' paper on the nature of Azote, &c. in Ann. of Phil. ii. 276, and to the 2d volume of his Traite de chim. ii. 339; to Davy, in Phil. Trans. 1810; and to J. Miers, on the composition of Azote, in Ann. of Phil. iii. 364, iv. 180, 260.

References. *Rutherford's Dissertation de Aere Mephitica. Scheele on Air and Fire. Lavoisier's Elements. Priestley on Air. For particulars concerning the preparation of Nitrogen, by the decomposition of Ammonia, see Berzelius,* i. 240.

Atmospheric Air.

Atmospheric air was for many centuries believed to be an elementary body. Although many philosophers deserve the merit of having thrown doubts over this opinion, its true nature was demonstrated about the same time by Scheele and Lavoisier.

Properties. Atmospheric air is a gaseous substance, transparent,

invisible, without odour or taste, and it is not sensible to the touch un-
less in motion; is perfectly elastic and compressible; has a pressure
at the level of the sea, equal to a weight of about 15 pounds on every
square inch of surface, and can support a column of water 34 feet high
and a column of mercury of 30 inches; has a density of 1,000, being
the standard with which the density of all other elastic fluids is com-
pared; 100 cubic inches of it in a pure and dry state weigh, according
to the recent experiments of Prout and others, 31 grains at 60° F. and
30 Bar.—*Henry*, i. 320.

The *chemical properties* of atmospheric air, are owing chiefly to the
oxygen which it contains, the presence of which is necessary to its
salubrity; it is a bad conductor of electricity, for when this fluid has
accumulated on the surface of a body, and passes to another body
through the air, it is always in the form of sparks; it is not changed
by high degrees of heat or cold; is changed with few exceptions by
the simple combustibles, at various temperatures, absorbing its oxygen
and liberating its nitrogen.

I shall now briefly notice some of the most important of the above
named properties.

Compressibility and Elasticity.—The *compressibility* of air is shown
by the fact that a quantity of it may be compressed or condensed, into
a very small compass; as is exemplified in the common fire syringe,
and in the air gun. In these cases, of course, the particles of which
the air is composed are brought nearer together by the compression.
The *elasticity* of air may be shown by putting a bladder half full of
air, under the receiver of an air pump and exhausting. As we with-
draw the air, or in other words diminish the pressure, the bladder be-
comes distended in consequence of the expansion of the air within it.
This elasticity is a force of considerable energy; for when air is high-
ly compressed its effort to recover its proper bulk is prodigious; and
so great that it will sometimes burst the strongest vessels. Hence the
well known danger of forcing too much air into the ball of an air gun:
it bursts and occasions great mischief.

The extreme compressibility and elasticity of the air accounts for
the facility with which it is set in motion, and the velocity with which
it is capable of moving. It is subject to the laws which characterize
elastic fluids in general It presses, therefore, equally on every side;
and when some parts of it become lighter than the surrounding por-
tions, the denser particles rush rapidly into their place and force the
more rarefied ones to ascend. The motion of air gives rise to various
familiar phenomena. A stream or current of air is wind, and an un-
dulating vibration excites the sensation of sound.

Weight and Pressure.—That the air is possessed of weight was first
suspected by Galileo in 1640, and afterwards placed beyond doubt by
the experiments of Torricelli and Pascal, in 1643. Torricelli ascer-
tained that when a glass tube of about three feet in length and closed
at one end, was filled with quicksilver and inverted in a basin of the
same fluid, the mercury fell about six inches, so that the atmosphere
appeared capable of counterbalancing a column of mercury of about
30 inches. By this experiment the *Barometer* was in fact constructed;
but it required the observation of Paschal that upon ascending a moun-
tain the quicksilver fell in the tube, because there was less air above to
press upon the surface of the metal in the basin,—to prove that an in-
strument of great value had thus been invented.

The pressure of the air, as is shown by the barometer, is extremely variable. It varies according to the elevation above the level of the sea, and on this principle the height of mountains is estimated. It also varies at the same place, and on this depends the indications of the barometer as a weather-glass. For although we are still ignorant of the cause, observation has fully proved, that the weather is commonly fair and calm when the barometer is high, and usually wet and stormy when the mercury falls.

It is obvious that as the pressure of the air diminishes as we ascend from the surface of the earth, the greater the elevation, the lighter must be the air. But it is not exactly known to what height the atmosphere extends. From calculations founded on the phenomena of refraction, its height is supposed to be about 45 miles ; and Dr. Wollaston estimates, from the law of the expansion of gases, that it is 40 miles. How far it extends beyond this point is a subject for speculation. Dr. Wollaston, from astronomical observations made by himself and Capt. Kater, infers that the atmosphere is of finite extent. On this point see Wollaston on the finite extent of the atmosphere.— *Phil. Trans.* 1822, *and in Ann. of Phil.* xx. 151.

These properties of the air, are most strikingly illustrated by the *Air Pump,* an instrument which in its construction resembles the common sucking pump, excepting that all the parts are more accurately made, the object being to exhaust the air as completely and as expeditiously as possible. If the receiver be placed on the plate of the pump and exhausted, we are unable to move it, because it is kept down by the weight of the air around it. Or if a long tube with a stop-cock be exhausted by the pump, and then have the cock opened under water, the fluid will be forced in by the pressure of the air on the surface of the water in the basin.

Constitution of the Air.—The researches of Davy, Dalton, Gay Lussac, Thomson and others, leave no doubt that pure atmospheric air consists of nearly 21 of oxygen and 79 nitrogen in the 100 volumes. But the atmosphere is never absolutely pure ; or rather, in addition to the above gases, it always contains a variable quantity of aqueous vapour and carbonic acid. According to Vogel and others, air within a certain distance from the sea, contains a little muriatic acid. [*Ann. of Phil.* xxii. 25,] and Liebig states that a trace of nitric acid is discoverable in rain which has fallen immediately after lightning. [*Henry's Chem.* i. 321.] The air of Paris and of many other places is said by Chevallier to contain ammonia and organic matters in solution ; while in that of London, sulphurous acid has been found. [*Lond. and Edin. Phil. Mag.* vi. 319.] In addition to these, the odoriferous matter of flowers and other volatile substances, are also frequently present in the air.

The presence of *watery vapour* in the air, may be shown by the experiments noticed under water, [p. 120.] The amount varies according to the temperature, and these variations are determined by the *Hygrometer.*

The presence of *carbonic acid* in the air may be shown by exposing to it a vessel of lime water. A pellicle soon forms on the surface of the solution, which by agitation sinks to the bottom and is soon succeeded by another. Upon analyzing this precipitate, it is found to be carbonate of lime, the carbonic acid of which must have been derived from the air with which the lime water was surrounded. But the

quantity of this gas in the air is quite inconsiderable, although it is liable to variation. According to Mr. Dalton it does not usually exceed 1 in 1000 parts; and T. Saussure has recently found that 10,000 parts of air contain 4·9 of carbonic acid as a mean, 6·2 as a maximum and 3·7 as a minimum.

The knowledge of the composition of the air, and of the importance of oxygen to the life of animals, naturally gave rise to the notion that the healthiness of the air, at different times, and in different places, depends on the relative quantity of this gas. It was, therefore, supposed that the purity of the atmosphere, or its fitness for communicating health and vigour, might be discovered by determining the proportion of oxygen; and hence the origin of the term *Eudiometer*, which was applied to the apparatus for analyzing the air. But this opinion, though at first supported by the discordant results of the earlier analyses, was soon proved to be fallacious. It appears, on the contrary, that the composition of the air is not only constant in the same place, but is the same in all regions of the earth, and at all altitudes. Air collected at the summit of the highest mountains, such as Mount-Blanc and Chimborazo, contains the same proportions of oxygen as that of the lowest valleys. The air of Egypt was found by Berthollet to be similar to that of France. The air which Gay Lussac brought from an altitude of 21.735 feet above the earth, had the same composition as that collected at a short distance from its surface.* Even the miasmata of marshes, and the effluvia of infected places, owe their noxious qualities to some principle of too subtile a nature to be detected by chemical means, and not to a deficiency of oxygen.† Seguin examined the infectious atmosphere of an hospital, the odour of which was almost intolerable, and could discover no appreciable deficiency of oxygen, or other peculiarity of composition.—(*Turner*.) For descriptions of various kinds of Eudiometers, see *Webster's Brande*, and *Ure's Dictionary*.

Concerning the nature of the union which exists among the several elastic fluids constituting the atmosphere, two opposite opinions prevail. By the greater part of chemists, it has been considered as a chemical compound, chiefly from the uniformity of its composition and from the fact that its several ingredients do not arrange themselves ac-

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* Mr. Faraday's analysis of air from the Arctic regions, shows a decided and constant difference between it and the air of London, of at least 1·374 per cent. [*App to Parry's 3d Voyage, Lond. ed. p.* 240.] And Mr. Dalton in a recent communication to the Royal Society, states that from numerous experiments made on air obtained from great heights, he is led to the conclusion that the proportion of oxygen to azote in the atmosphere on the surface of the earth is not precisely the same at all places and times; and that in elevated regions this proportion is somewhat less than at the surface of the earth, but not nearly so much as the theory of mixed gases would require, the reason for which he supposes to be, the incessant agitation of the atmosphere produced by winds or other causes.—*Lond. and Edin. Phil. Mag.* xi. 195.

† An interesting fact was observed by Dr. Prout, while engaged in an extensive series of experiments on the weight of dry atmospheric air: viz. that during the existence of the epidemic cholera in London in 1832, the air uniformly possessed a weight above the usual standard. "It would seem," says he, "as if some heavy foreign body had been diffused through the lower regions of the atmosphere about this period, and which was somehow or other connected with the disease in question."—*Reports of the Brit. Association for 1832.*

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cording to their respective specific gravities. On the other hand, Mr. Dalton has advanced the theory that, of the various elastic fluids constituting the atmosphere, the particles of one have neither attractive nor repulsive power towards those of another; but that the weight or pressure upon any one particle of a fluid mixture of this sort, arises solely from the particles of its own kind. According to this hypothesis, oxygen, nitrogen and carbonic acid gases, (or indeed any number,) may exist together, under any pressure, and at any temperature, while each of them, however paradoxical it may at first appear, occupies the space allotted for all. Each ingredient of the atmosphere, on this view, exerts its own separate pressure in supporting the mercury of the barometer. This theory appears to be loaded with fewer difficulties than that which considers the constituents of the atmosphere to be held together by chemical affinity.

But our limits will not permit a detail of the arguments in its support. Mr. Dalton has fully explained his views respecting the constitution of the atmosphere, in the *Phil. Trans. for* 1826.

On this subject see also the papers of Mr. Graham and Dr. Mitchell of Philadelphia, on the diffusion of the Gases.—*Journal of the Roy. Ins.* ii. 101. *Jour. of Science, N. S.* vi. 74.

REFERENCES. *Priestley on Airs. Scheele's Essay on Air and Fire. Lavoisier's Elements of Chemistry. Thenard's Traité de Chim:* i. 272. *Art. Aeronautics, in the Supplement to the Encyclopedia Britannica, containing an account of the Aerial Ascent of M. M. Biot and Gay Lussac, and of their observations upon the higher Atmosphere, &c.*

NITROGEN AND OXYGEN.

We are at present acquainted with five definite compounds of these substances, the composition of which, as determined by Gay Lussac, Henry, and Davy, is as follows:

		By volume.		By weight.	
Protoxide of nitrogen,	.	100 N.	50 O.	14 N.	8 O=22.
Deutoxide of nitrogen,	.	100 N.	100 O.	14 N.	16 O=30.
Hyponitrous acid,	. .	100 N.	150 O.	14 N.	24 O=38.
Nitrous acid,	. . .	100 N.	200 O.	14 N.	32 O=46.
Nitric acid,	. . .	100 N.	250 O.	14 N.	40 O=54.

Protoxide of Nitrogen—Atom. Num. 22— *Symb.* O+N—*Sp. gr.* 1·527
air=1.

This curious substance was discovered by Priestley, in 1772, and has been examined with much care by Berthollet, Davy, Gay Lussac and Thenard. It has successively received the names of *Dephlogisticated Nitrous Gas, Nitrous Oxide,* and *Gaseous Oxide of Azote ;* but the appellation above given is in strict conformity with the principles of chemical nomenclature.

PROPERTIES. A colourless gas, without odour, and of a slightly sweetish taste ; does not affect vegetable blues, even when mixed with atmospheric air ; supports combustion, most substances burning in it with greater energy than in the atmosphere ; it is respirable, producing when breathed, a high degree of excitement, similar to that of the early stages of intoxication, but when animals are wholly confined in it they die very speedily ; it is absorbed by water at 60° F. in the pro-

portion of three-fourths of its volume, and hence it should be collected over warm water; it is decomposed by heat and by the electric spark; it is liquified by pressure. It also possesses, as well as the deutoxide, the property of combining with the pure alkalies.

It supports combustion.—The glowing wick of an extinguished taper or candle, when introduced into a vessel of this gas, is immediately kindled by it into a flame. Iron wire and red hot charcoal burn in it, with nearly the same splendour as in oxygen gas, but for a shorter time. Phosphorus introduced into it, in a state of active inflammation, burns with great violence, almost approaching to explosion. When mixed with hydrogen it will detonate, either by the application of flame or the electric spark.

In each of the above cases, the combustible combines with oxygen, forming water, and oxide, or an acid, and nitrogen is set at liberty.

It is respirable when mixed with atmospheric air.—It has been observed that animals wholly confined in pure protoxide of nitrogen speedily die. It may, however, be taken into the lungs without being fatal, because it is mixed and diluted with the air present in that organ. One of the most extraordinary properties of this gas, first ascertained by the bold experiments of Davy, in 1799, is that it produces, when breathed, a transient intoxication, or violent exhilaration.

To administer the gas, it may be introduced into an oiled silk bag or clean bladder, furnished with a stop-cock, and it may be breathed repeatedly from the bag and back again, as long as it will last. The sensations produced are, in general highly pleasurable and resemble those attendant on the early period of intoxication. Great exhilaration, an irresistable propensity to laughter, a rapid flow of vivid ideas, and an unusual fitness for muscular exertion, are the ordinary feelings it produces. But the effects of the gas are different upon persons of different temperaments and constitutions. Some interesting notices of its operation upon distinguished men in England, are to be found in Ure's Chemical Dictionary. In general these feelings of exhilaration are not followed by any thing more than a slight sensation of languor, probably from the effects of muscular exertion alone ; but it should not be concealed that its administration is occasionally attended with unpleasant consequences, and should, upon the whole, be rather discouraged than recommended. Two cases of this sort are related by Professor Silliman, as having occurred at New Haven.— *Amer. Jour.* v. 194.

PREPARATION. The protoxide of nitrogen may be obtained,

1. By exposing deutoxide of nitrogen for a few days to iron filings, or to various other bodies strongly attracting oxygen, the former gas is changed into the protoxide, one half of its oxygen combining with the metal.

2. By the decomposition of the nitrate of ammonia, a salt obtained by the action of pure nitric acid upon the carbonate of ammonia, and subsequent evaporation. When this salt is put into a glass retort and exposed to the temperature of between 4 and 500°, it liquifies, bubbles of gas begin to rise from it, and in a short time a brisk effervescence ensues, which continues till the whole of the salt disappears. The heat should be cautiously regulated to avoid explosion, which takes place when the temperature reaches that of a red heat. The gas

should be collected over warm water and allowed to stand a short time before it is used.

The above process may be easily explained. Nitrate of ammonia consists of nitric acid and ammonia, or of 5 atoms of oxygen and 1 atom of nitrogen, in the nitric acid; and of 3 atoms of hydrogen, and 1 atom of nitrogen, in the ammonia. There are, therefore, in one atom of nitrate of ammonia.

Nitrogen	.	.	.	.	2 atoms.
Oxygen	.	.	.	.	5 atoms.
Hydrogen	.	.	.	.	3 atoms.

Now by the application of heat the 3 atoms of hydrogen combine with 3 atoms of oxygen and form water, while the remaining atoms of oxygen convert the nitrogen into protoxide of nitrogen.

REFERENCES. *Davy's Elements of Chem. Phil. Gay Lussac and Thenard, Phys. Chem. Researches. Faraday, on impurities in Nitrous Oxide, Brande's Jour.* vi. 360.

Deutoxide of Nitrogen—Atom. Num. 30—*Symb.* $2O+N$—*Sp. gr.* 1.041
air$= 1$.

SYN. *Nitrous Gas.—Nitric Oxide.—Binoxide of Nitrogen.*

The discovery of this substance is due to Hales; but its properties were first investigated by Priestley.

PROPERTIES. A colourless gas, without action upon litmus; is sparingly absorbed by water; extinguishes most burning bodies, but charcoal and phosphorus, if immersed in it when in a state of vivid combustion, burn with increased brilliancy; is quite irrespirable, exciting a strong spasm of the glottis, as soon as an attempt is made to inhale it; is decomposed by heat and electricity; when mixed with oxygen gas assumes an orange red colour, owing to its combination with an additional quantity of oxygen—the same thing takes place when this gas comes in contact with atmospheric air, affording a convenient test of its presence; when mixed with hydrogen it burns with a green flame, but does not explode by the electric spark.

Action of Oxygen Gas.—When deutoxide of nitrogen is mixed with oxygen gas, atmospheric air, or any gaseous mixture that contains oxygen in an uncombined state, dense suffocating vapours, of an orange red colour, are produced, called *nitrous acid vapours,* which are copiously absorbed by water, and communicate acidity to it. This effect can be shown by the following experiment.

Exp. Paste a sheet of litmus paper within a glass jar; near the bottom, and into the jar, filled with and inverted in water, admit so much nitrous gas, previously well washed, as will displace the water below the level of the paper. The colour of the litmus will remain unchanged; but on admitting oxygen gas it will be immediately reddened.

It is from this property of absorbing oxygen, but no other gas, that nitrous gas has been applied to the purpose of *Eudiometry,* or of ascertaining the purity of atmospheric air, which was formerly supposed to depend upon a varying proportion of that gas. The sources of error in its employment in this mode, have hitherto been considered such as to forbid our relying implicity on the results which it may afford. But

Dalton and Gay Lussac maintain that it may nevertheless be employed in eudiometry; and have described the precautions which are required to ensure accuracy. Mr. Dalton has given his process in the 10th volume of the Annals of Philosophy; and further directions have been published by Dr. Henry, in his Elements. The method of Gay Lussac, which is preferred by Dr. Turner, may be found in the 2d volume, p. 247, *Memoires d'Arcueil.*

PREPARATION. The deutoxide of nitrogen may be easily obtained by pouring upon filings or turnings of copper, put into a retort or gas bottle, some nitric acid diluted with twice its bulk of water; an action ensues, red fumes are produced, and there is a copious evolution of the gas which may be collected over water. The first portions should be rejected, as containing nitrogen and nitrous acid gases. The deutoxide of nitrogen is presently recognized, by the red fumes which it produces when brought into contact with air. During this process a portion of the nitric acid is decomposed; part of its oxygen uniting with the copper, converts it into the peroxide of copper; while another part is retained by the nitrogen of the nitric acid, forming the deutoxide of nitrogen. The peroxide of copper attaches itself to some undecomposed nitric acid, and forms the blue nitrate of copper. Many other metals are oxidized by nitric acid, with the disengagement of a similar compound; but none, mercury excepted, yields so pure a gas as copper.

REFERENCES. *Davy's Elements of Chem. Phil. Gay Lussac, Mem. d'Arcueil,* ii.

Hyponitrous Acid—Atom. Num. 38—*Symb.* 3O+N.

This acid, the existence of which was first pointed out by Gay Lussac, is said to be formed, when 400 measures of deutoxide of nitrogen are mixed with 100 of oxygen gas, both quite dry, and the resulting orange fumes are exposed to a cold of 0° F. when it is condensed into a liquid.

Anhydrous liquid hyponitrous acid is colourless at 0° F. and green at common temperatures. It is so volatile, that in open vessels the green fluid wholly and rapidly passes off in the form of an orange vapour, which is said by Mitscherlich to have a density of 1·72. On admixture with water it is converted into nitric acid and deutoxide of nitrogen, the latter escaping with effervescence; but when much nitric acid is present, the hyponitrous is changed into nitrous acid, the presence of which imparts several shades of colour, orange, yellow, green and blue, according as its quantity is more or less predominant.—*Turner.*

This acid does not combine directly with basis, but the hyponitrites of the alkalies and alkaline earths may be obtained by heating the corresponding nitrates to a gentle red heat; and the hyponitrite of the oxide of lead may be formed by boiling a solution of the nitrate of that oxide with metallic lead.

Hyponitrous acid possesses the singular property of combining with several other acids, especially with the sulphuric. If we pass a mixture of four volumes of deutoxide of nitrogen and one volume of oxygen gas through concentrated sulphuric acid, we obtain a crystalline mass composed of sulphuric acid, hyponitrous acid and water. This compound is formed in large quantity during the manufacture of sul-

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phuric acid, and its production seems to be an essential part of that process.

Nitrous Acid—Atom. Num. 46—Symb. 4O+N.

This acid appears to have been known for some time, but was confounded with nitric acid, being known under the name of *Fuming Nitrous Acid.* Its true nature has been made known by Davy, Gay Lussac and Dulong.

PROPERTIES. Nitrous acid exists in a gaseous and liquid state.

The *gaseous* acid is characterized by its orange red colour ; is quite irrespirable, exciting great irritation and spasm of the glottis, even when moderately diluted with air; supports the combustion of burning phosphorus and of a lighted taper, but extinguishes burning sulphur.

The *liquid* anhydrous acid is powerfully corrosive, has a strong acid taste, and pungent odour; is of a yellowish orange colour at the ordinary pressure and temperature, but at low temperatures becomes colourless ; has a density of 1·451 ; preserves the liquid form at the ordinary temperature and pressure, and boils at 82° F. ; evaporates with great rapidity when exposed to the atmosphere, forming common nitrous acid vapours, which when once mixed with air, or other gases, require intense cold to condense them.

PREPARATION. This acid never exists in nature. The gaseous acid may be formed by mixing oxygen gas with the deutoxide of nitrogen. The operation, however, must not be conducted over water or mercury. The presence of the former determines the production of nitric acid ; the latter is oxidized by the nitrous acid, and therefore decomposes it. Sir H. Davy made this compound by mixing two measures of the deutoxide of nitrogen, and one of oxygen, free from moisture, in a dry glass vessel, previously exhausted by an air pump. Nitrous acid vapours were produced, and a contraction ensued, amounting to about one half the volume of the mixed gases.

The liquid anhydrous acid may be obtained by a more easy process than the above. For this purpose dry and neutral nitrate of lead is to be exposed to heat in a glass retort. The nitric acid of the salt is in this manner resolved into nitrous acid and oxygen; and if the products are received in vessels kept moderately cool, the greater part of the former condenses into a liquid.

REFERENCES. *Davy's Elements of Chem. Phil. Dulong, in Ann. de Chim. et de Ph.* ii. 317. *R. Philips and Dr. Hope's controversy concerning its preparation, Ann. of Phil.* xvii. 59, 189. xviii. 24.

Nitric Acid—Atom. Num. 54—Symb. 5O+N—Sp. gr. 1·510 water = 1.

SYN. *Spirits of Nitre. Aqua Fortis.*

This acid is said to have been discovered about 1225, by Ramond Lully, in distilling a mixture of nitrate of potassa and clay ; but its nature was not well understood until 1785, when it was examined by Cavendish. Since that time its properties have been investigated by Davy, Dalton and Gay Lussac.

PROPERTIES. Nitric acid, in its highest state of concentration, is liquid, odorous, white and very corrosive; destroys the skin and

changes it to a yellow colour; is eminently poisonous; possesses acid properties in a high degree, a single drop of it, though largely diluted with water, reddening litmus permanently; in its most pure and concentrated state has the specific gravity of 1·50 or 1·510, containing still in this state a considerable quantity of water from which it cannot be separated without decomposition or by uniting with some other body; boils at 248° F. and may be distilled without change; is frozen by cold, the temperature at which congelation takes place varying with the strength of the acid, the strongest freezing at 50° below zero; it is decomposed by solar light and by several of the combustibles; forms with bases, salts which are called *Nitrates*.

It is decomposed by solar light.—When very concentrated, liquid nitric acid becomes coloured by exposure to the sun's light, passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun with oxygen, in consequence of which the proportion of that principle to the nitrogen is diminished.— *Henry*, i. 353.

By exposing it to the sun's rays in a gas bottle, the bent tube of which terminates under water, oxygen gas may be procured.

It is decomposed by various combustible bodies.—As this acid retains its oxygen with but little force, it is decomposed by all combustibles, which are oxygenized by it, with more or less rapidity, in proportion to their affinity for oxygen.

1. When brought into contact with hydrogen gas at a high temperature, by transmitting them together through an ignited porcelain tube, a violent detonation ensues. This experiment, therefore, requires great caution. Dr. Priestley found also that hydrogen gas, after being used to displace nitric acid from a bottle inverted in that liquid, had become explosive.

2. Poured on perfectly dry and powdered charcoal, it excites the combustion of the charcoal, which becomes red hot, and emits an immense quantity of fumes. Phosphorus when thrown into the concentrated acid takes fire and burns with much splendour, phosphoric acid being formed.

3. It also inflames essential oils, (as those of turpentine and cloves) when suddenly poured on them. In these experiments, the acid should be poured out of a bottle, tied to the end of a long stick; otherwise the operator's face and eyes may be severely injured.

4. Nitric acid is decomposed by boiling it in contact with sulphur, which attracts the oxygen and forms sulphuric acid.

5. This acid is also decomposed by metals; as iron, tin, copper, &c. with various phenomena, according to the affinity of each metal for oxygen. This may be seen by pouring some strong nitric acid on iron filings or powdered tin. Violent heat, attended with red fumes, will be produced and the metals will be oxidized. According to Dumas, when the acid has a density of exactly 1·48, it does not act upon the metals. —*Traité de Chim.* i. 328.

Action of deutoxide of nitrogen.—When a current of deutoxide of nitrogen is transmitted through nitric acid, that gas, by taking oxygen from the nitric, is converted into the nitrous acid, and a portion of nitric acid, by losing oxygen, passes into the same compound. The

nitrous acid, thus derived from two sources, gives a colour to the nitric acid, the depth and kind of which depend on the strength of the acid. On saturating with deutoxide of nitrogen four separate portions of nitric acid of the densities 1·15, 1·35, 1·40, and 1·50, the colour will be blue in the first, green in the second, yellow in the third, and brownish-red in the fourth; and acid of 1·05 is not coloured at all. An apparatus such as is here presented is suitable for exhibiting these experiments. Copper turnings must be put into the bottle with a long funnel, and the nitric acid in the other. After adjusting the connecting tubes diluted nitric acid is poured upon the copper through the tube funnel and the excess of gas may be collected over the pneumatic trough.
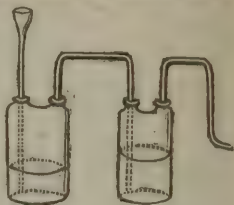
PREPARATION. This may be affected in the following ways.

1. The direct combination of nitrogen and oxygen, affording a decisive synthetic proof of the nature of this acid, may be effected by passing electric sparks through a mixture of nitrogen and oxygen gases. The experiment is an extremely laborious one, and requires for its performance, a powerful electrical machine.—*See Cavendish, Phil. Trans.* lxxv. *Henry's Chem.* i. 346.

2. This acid may be readily produced by passing the deutoxide of nitrogen very slowly into oxygen gas, standing over water. By this operation four volumes of the former combine with three of the latter, and the compound, therefore, must consist of two volumes nitrogen and five volumes oxygen, or by weight of one proportion of nitrogen and five proportions of oxygen.

3. The liquid nitric acid of commerce is abundantly obtained from the decomposition of the nitrates by means of sulphuric acid; and common nitre or nitrate of potassa being the cheapest, is always selected for this purpose. This salt previously well dried, is put into a glass retort, and a quantity of the strongest sulphuric acid is poured upon it. On applying heat, ebullition ensues, owing to the escape of nitrous acid vapours, which must be collected in a receiver kept cold by moist cloths. The heat should be steadily increased during the operation, and continued as long as any acid vapours come over. An apparatus similar to that figured on page 112, may be employed for preserving this acid in small quantities.

There is some difference among chemists as to the best proportions for forming nitric acid. The London college recommends equal weights of nitre and sulphuric acid; the Edinburgh and Dublin colleges employ three parts of nitre to two of the acid. According to Thomson, when 6 1-8 parts of the strongest sulphuric acid of commerce are mixed with 12 3-4 parts of nitre thoroughly freed from water and perfectly pure, the acid which comes over is the strongest that can be procured, having a specific gravity of 1·55, and consists of one atom of acid and one atom of water. When 12 1-4 parts of sulphuric acid are mixed with 12 3-4 parts of pure anhydrous nitre, the whole nitric acid may be obtained without loss; but its specific gravity is only 1·4855, and it is a compound of one atom real acid and two atoms water.—*First Princip.* i. 113.

In the large way, and for purposes of the arts, it is usual to substitute earthen or cast iron retorts, made extremely thick, for those of glass. An earthen head is adopted, and this is connected with a range of proper condensers. The strength of the product is varied also by putting more or less water into the receiver.

IMPURITIES.—The nitric acid of commerce is seldom perfectly pure. It may contain both sulphuric and muriatic acids; the former being derived from the acid which is used in the process: the latter from the muriate of soda which is sometimes mixed with the nitre. These impurities can be detected by adding a few drops of a solution of muriate of baryta and nitrate of silver to separate portions of nitric acid, diluted with three or four parts of distilled water.* If the solution of muriate of baryta cause a cloudiness or precipitate, sulphuric acid must be present; if a similar effect be produced by nitrate of silver, the presence of muriatic acid may be inferred. Nitric acid is purified from sulphuric acid by re-distilling it from a small quantity of the nitrate of potassa, with the alkali of which, the sulphuric acid unites and remains in the retort. To separate muriatic acid, it is necessary to drop a solution of nitrate of silver into nitric acid as long as a precipitate forms, and draw off the pure acid by distillation. It should be kept in well stopped glass bottles, and in a dark place, as the light effects its decomposition.

TESTS OF NITRIC ACID. Leibig, some time since, proposed the blue colour of the sulphate of indigo as a test for the presence of nitric acid, but this substance is decolourized by so many agents that no reliance can be placed in its indications. A very delicate and apparently unobjectionable test, is the orange red followed by a yellow colour, which nitric acid communicates to morphine. The supposed nitrate is heated in a test tube with a drop of sulphuric acid and then a crystal of morphine is added. For this fact we are indebted to Mr. O'Shaugnessy.— *Lancet* 1829—30.

ACTION ON THE ANIMAL ECONOMY.—This substance is of course highly poisonous, when taken internally in its concentrated form, causing death speedily, though never suddenly. In these cases neutralizing agents should be administered as soon as possible, to prevent the action of the poison.—*See Beck's Medical Juris.*

USES.—Nitric acid is of considerable use in the arts. It is employed for etching on copper, as a solvent of tin to form with that metal a mordant for some of the finest dyes; in metallurgy and assaying; in various chemical processes, on account of the facility with which it parts with oxygen and dissolves metals; in medicine as a tonic, &c. For the purposes of the arts it is commonly used in a diluted state and much contaminated with the sulphuric and muriatic acids, under the name of *Aqua Fortis*. This is generally prepared by mixing common nitre with an equal weight of sulphate of iron, and half its weight of the same sulphate calcined, and distilling the mixture; or by mixing

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* In applying tests to the acids it is always necessary to dilute them with distilled water, as the strong acids in many cases give precipitates with saturated solutions of salts, whether pure or not. The reason of this is that the acids combine with the water that retains the salt in solution, while it is precipitated in the solid form.

the nitre with twice its weight of dry powdered clay and distilling in a reverbatory furnace. Two kinds are found in the shops, one called *double aqua fortis*, which is about half the strength of nitric acid; the other simply *aqua fortis*, which is half the strength of the double.— *Ure's Chem. Dict.*

REFERENCES. *Davy's Elements of Chem. Phil. Dalton's New System of Chem. Gay Lussac's Mem. d'Arcueil*, ii. *and Ann. de Chim. et de Phys.* i. 394. *Thenard, Traité de Chim. Dr. Ure and R. Philips' controversy concerning the constitution of Liquid Nitric Acid, Brande's Jour.* iv. 291, v. 163, vi. 242, vii. 171. *Chaptal's Account of, and its Manufacture, Chem. applied to the Arts. On the same subject, see Aikin's Dict. of Chem.; Gray's Operative Chem.; and Dumas' Traité de Chim. &c.*

Nitro-Muriatic Acid.

This term has been applied to the *Aqua Regia* of the alchemists.— an acid, which may be formed by mixing two parts by weight of nearly colourless nitric, with one of liquid muriatic, acid. Proust employs only one of nitric to four of muriatic acid, which are generally thought to be the best proportions. The mixture evolves chlorine, a partial decomposition of both acids having taken place, and water, chlorine and nitrous acid gas, are thus produced; that is, the hydrogen of the muriatic acid abstracts oxygen from the nitric to form water : the result must be chlorine and nitric acid.—*Davy, in Brande's Jour.* i. 67.

The nitro-muriatic acid does not form, with alkaline or other bases, a distinct genius of salts, entitled to the name of nitro-muriates; for, when combined with an alkali or an earth, the solution yields, on evaporation, a mixture of a muriate and a nitrate; and metallic bodies dissolved in it yield muriates only.—*Henry*, i. 355.

The most remarkable property of nitro-muriatic acid is that of dissolving gold and platinum.

- Nitro-Hydrofluoric Acid.

This is a name given to a mixture of nitric and hydrofluoric acids which Berzelius has proposed to employ in some cases. It is ascertained that all the metals which resist the action of the aqua regia are dissolved by this mixture and it is therefore a very important re-agent. The principles of its preparation are similar to those of the Nitro-muriatic.—*Dumas*, i. 342.

NITROGEN AND CHLORINE.

Chloride of Nitrogen—Atom. Num. 155·8—*Symb.* 4Cl+N— *Sp. gr.* 1·653 water=1.

An extraordinary compound, discovered by Dulong, in 1811—and which has been subsequently examined by Sir H. Davy and others.

PROPERTIES. An oily liquid, of a yellow colour, and an irritating and peculiar odour, analogous to that of chloro-carbonic acid; does not congeal by the intense cold produced by a mixture of snow and salt; may be distilled at 160° F. without change; but at a temperature between 200° and 212° F. it explodes, and is decomposed into chlorine

and nitrogen ; explodes also upon the contact of phosphorus and many of the oils at common temperatures ; vaporizes rapidly when in contact with air, emitting a suffocating odour.

Explodes upon the contact of certain combustibles.—Chloride of nitrogen is one of the most explosive substances yet known, and it was the cause of serious accidents both to the discoverer and to Sir H. Davy. Great caution is therefore necessary in its preparation and exhibition. From the experiments of Messrs. Porrett, Wilson and Kirk, it appears that it may be exploded by the mere contact of certain combustibles, as phosphorus, and the fixed and volatile oils. Olive oil is one of the best for exhibiting the nature of the chloride, as it seldom, if ever fails to produce an explosion.—*Nicholson's Jour.* xxxiv.

PREPARATION. Chlorine and nitrogen have but a slight affinity for each other ; they do not combine at all when presented to each other in the gaseous form, and when combined separate with great facility. The chloride of nitrogen can only be formed by presenting chlorine to nascent nitrogen. For this purpose some salt of ammonia is employed. Its formation is owing to the decomposition of the ammonia, (being a compound of hydrogen and nitrogen) the hydrogen combines with a portion of the chlorine and forms muriatic acid, while the nitrogen combines with another portion of the chlorine and gives rise to the chloride of nitrogen.

The simplest mode of obtaining this compound consists in filling a perfectly clean glass basin A with a solution of about one part of sal-ammoniac in twelve of water, and inverting into it a tall jar of chlorine B.

The saline solution is gradually absorbed and rises into the jar, a film forms on its surface and acquires a deep-yellow colour ; at length small globules, looking like yellow oil, collect upon its surface, and successively fall into the liquid beneath. The drops of chloride of nitrogen, as they descend, should be collected in a small saucer of lead C, placed for that purpose under the mouth of the bottle. In this they may be exploded by a long rod with the extremity dipped in oil.
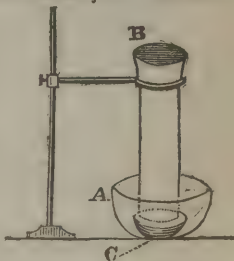
REFERENCES. *Davy in Phil. Trans.* 1813, *and notices of the same in Ann. of Phil.* i. 63, 71. ii. 150. *Notice of Dulong's Experiments, Ann. of Phil.* iv. 306.

NITROGEN AND IODINE.

Iodide of Nitrogen—Atom. Num. 392—*Symb.* 31+N.

Discovered by M. Courtois.

PROPERTIES. A dark coloured powder, which explodes spontaneously when dry, and with a slight degree of heat when moist ; emits heat and light during the explosion, and iodine and nitrogen are set free ; is readily decomposed by the alkalies ; and according to the experiments of M. Colin, it consists of three atoms of iodine and one atom of nitrogen.

PREPARATION. Iodine and nitrogen cannot be made to combine directly, but combination takes place when the nitrogen, in a nascent state, is brought into contact with iodine. This compound may be obtained by putting iodine into a solution of ammonia at ordinary temperatures. A portion of the ammonia is soon decomposed, and there result an iodide of nitrogen which falls down in the form of a blackish precipitate, and a hydriodate of ammonia which remains in solution. At the expiration of half an hour, the powder may be thrown upon a filter and washed, but the washings should not be carried too far, otherwise there is danger of its spontaneous decomposition and explosion while on the filter.

REFERENCES. *Colin on some combinations of Iodine, Jour. de Phys. or Repertory of Arts,* 2d *Ser.* xxvi.

NITROGEN AND HYDROGEN.

Ammonia—Atom. Num. 17.—*Symb.* 3 H+N. *Sp. gr.* 0˙5967 air =1.

Known to the alchemists, though not in its purity, under the names of *Hartshorn, Volatile Alkali, Spirit of Sal-ammoniac, &c.* Dr. Black first pointed out the difference between pure ammonia and the carbonate. Dr. Priestley first obtained it in its purest form, that of a gas, which he termed *Alkaline Air.*

PROPERTIES. Ammonia in its pure state is a gaseous substance, without colour, of a strong and pungent odour, acting powerfully on the eyes and nose; is quite irrespirable, but when diluted with air, may be taken into the lungs with safety; extinguishes burning bodies and is not inflamed by their approach, but is however in a low degree inflammable, the flame of a candle being somewhat enlarged when immersed in it, and tinged of a yellow colour, at the moment of its being extinguished; becomes a transparent colourless liquid at the temperature of 50° F. and under a pressure equal to 6˙5 atmospheres; possesses alkaline properties in a very marked degree, changing the blue of litmus to green, and the yellow of turmeric to brown; is decomposed when subjected in small quantities to the action of electricity; has a powerful affinity for water, and must therefore be collected over mercury.

It is inflammable.—Ammoniacal gas is not sufficiently inflammable to burn, when in contact with common air. But when expelled from the extremity of a pipe having a small aperture surrounded by oxygen gas, it may be kindled, and it then burns with a pale yellow flame, the products of its combustion being water and nitrogen gas.—*Henry,* i. 426.

It is partly decomposed by chlorine and iodine.—When chlorine gas is mixed with pure ammonia, a sheet of white flame pervades the mixture; part of the ammonia is decomposed, the chlorine is converted into muriatic acid, which uniting with the undecomposed ammonia is deposited in the form of muriate.

Exp. The simplest way of showing the effect produced by mixing these two gases, is to invert a matrass with a conical neck and wide mouth, over another with a taper neck, containing a mixture of muriate of ammonia and lime, heated by a lamp. As soon as the upper vessel seems to be full of ammonia, by the overflow of the pungent

gas, it is to be cautiously lifted up, and inserted in a perpendicular direction, into a wide mouthed glass decanter or flask, filled with chlorine. On seizing the two vessels thus joined, with the two hands covered with gloves, and suddenly inverting them like a sand glass, the heavy chlorine and light ammonia, rushing in opposite directions, unite with the evolution of flame.—*Ure's Chem. Dict.*

Ammonia and iodine also unite, according to M. Colin, at ordinary temperatures, provided both are perfectly dry. By their simple contact a viscid liquid is formed, which, when brought into contact with water, gives rise to a black compound, (iodide of nitrogen,) which fulminates when slightly compressed.—*Ann. de Chim.* xci. 261.

Ammoniacal gas is absorbed by water.—A drop or two of water being admitted to a jar full of this gas, confined over mercury, the gas will be immediately absorbed, and the mercury will rise so as to fill the whole of the jar, provided the gas be sufficiently pure. Ice produces the same effect in a still more remarkable manner. Water by saturation with this gas, acquires its peculiar smell, and constitutes what has been called liquid ammonia, but which is more properly a solution of pure ammonia in water.

Alcohol also absorbs several times its bulk, and affords a solution of ammonia which possesses the strong smell and other properties of the gas. This is commonly called *Spirits of Hartshorn.*

Composition.—The composition of ammonia has occupied much of the attention of chemists. Hydrogen and nitrogen gases do not unite directly, and therefore we have no direct synthetic proof of the constitution of ammonia. But it is produced synthetically during the decomposition of many animal substances; it is also formed during the violent action of nitric acid upon some of the metals, and by moistened iron filings exposed to an atmosphere of nitrogen. In these cases the nascent gases unite, so as to form a portion of ammonia.

But the composition of ammonia has been determined analytically with the greatest exactness. When a succession of electric sparks is passed through ammoniacal gas, it is resolved into its elements; and the same effect is produced by conducting ammonia through porcelain tubes, heated to redness. A. Berthollet analyzed ammonia in both ways, and ascertained that 200 measures of that gas, on being decomposed, occupy the space of 400 measures, 300 of which are hydrogen and 100 nitrogen. Dr. Henry has made an analysis of ammonia by means of electricity, and his experiment proves beyond a doubt that the proportions above given are rigidly exact.—*Ann. of Phil.* xxiv. 346.

PREPARATION. Ammonia may be obtained in the form of gas in either of the following ways:

1. Mix together equal parts of muriate or sulphate of ammonia and dry quick-lime, each separately powdered, and introduce them into a small glass bottle or retort. Apply the heat of a lamp, and receive the gas that is liberated, over the mercurial trough.

2. To a saturated solution of ammonia in water, or the pure liquid ammonia in a gas bottle, apply the heat of a lamp; and collect the gas as in the former case. A small quantity of this gas, however, may be prepared without a mercurial trough, as follows. Put two or three drachms of the ammoniacal solution into a Florence flask and adapt a bent glass tube to it, supporting it in the manner represented in the

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figure. On heating the aqueous ammonia by a spirit lamp, ammoniacal gas is abundantly disengaged, and may be collected by displacement in an inverted jar or bottle. The vessel in which the gas is collected must be inverted, as it is lighter than atmospheric air. When the bottle or jar is full of gas, which may be known by the dense white vapours formed when a rod dipped in muriatic acid is brought near the mouth, it must be removed and corked tightly. The bent tube is fitted to the flask by being passed through a cork.

Ammonia has heretofore been found native only in combination with muriatic and phosphoric acids in the urine; with sulphuric acid in some mines of alum; with carbonic and acetic acid, &c. in putrid animal matter, and in the urine of all animals.
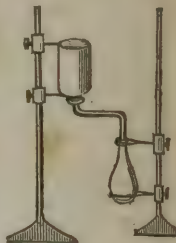
Solution of Ammonia in water.—This is commonly but incorrectly known by the name of *liquid ammonia*. A good process for preparing it is, to mix together equal parts of muriate of ammonia and well burned quick-lime. The lime is slaked with a half of its weight of water, and then allowed to cool in a covered vessel to protect it from the carbonic acid of the air. It is then mixed in a mortar with the muriate of ammonia, previously reduced to a fine powder; and the mixture is put into an iron or glass retort, and subjected to heat. The ammoniacal gas is conducted into a quantity of distilled water equal to the weight of the salt employed.

The concentrated solution of ammonia as thus procured is a clear colourless liquid having a specific gravity of about 0·954, and possessing the peculiar pungent odour, taste, alkalinity and other properties of the gas itself. On account of its great volatility, it should be preserved in well stopped bottles, a measure which is also required to prevent the absorption of carbonic acid.—At the temperature of 130° F. it enters into ebullition, owing to the rapid escape of pure ammonia; but the whole of the gas cannot be expelled by this means, as at last the solution itself evaporates. It freezes at about the same temperature as mercury.

Tables are given by Sir H. Davy and Dalton, showing the quantity of real ammonia contained in 100 parts of solutions of different densities.—*Elements of Chem. Phil. Henry*, i. 429.

Tests. The presence of ammonia may always be detected by its odour, by its temporary action on the yellow of turmeric, and by forming dense white fumes, the muriate of ammonia, when a glass rod moistened with muriatic acid is brought near it. Hydrated oxide of lead is also a test of ammonia.

Action on the animal economy. Cases are mentioned where the solution of ammonia caused death in the space of a few minutes; and in a late work, Orfila adds a caution against its too free use with persons who have fainted. If inspired too long, the vapour inflames the throat and lungs, and destroys the individual.—*Beck's Med. Juris. 6th Edition.*

References. *For a very elaborate account of Ammonia, and its action on various substances, see Thenard, Trait. de Chim. Berzelius on*

the nature of Ammonia, Ann. of Phil. ii. 276, *and Trait. de Chim.* ii. 320. *Dalton, Ann. of Phil.* ix. 186, *on the same subject. Phillips and Hope's controversy on the preparation of solution of Ammonia, Ann. of Phil.* xvii. 30, xviii. 191. *Faraday on the combination of Chlorides with Ammonia, Brande's Jour.* v. 74.

SALTS OF AMMONIA AND THE FOREGOING ACIDS.

The salts of ammonia are generally colourless and solid at common temperatures, except the subfluoborate, which is a liquid. They are mostly neutral; of an acrid taste; those with an excess of base having an ammoniacal odour. A few of them are acid; almost all crystallizable; when exposed to heat are either wholly or in part volatilized, depending upon the nature of the acid whether gaseous or fixed. They are decomposed by chlorine at common temperatures, and when mixed with potassa, soda, lithia, baryta, strontia or lime, ammonia is evolved.

REFERENCES. *Dr. Ure's experimental researches on the Ammoniacal Salts, Ann. of Phil.* x. 203, 278.

Chlorate of Ammonia.—Crystallizes in fine needles; of a very sharp taste; detonates when thrown upon hot coals, and when submitted to a gentle heat in a retort, is rapidly decomposed and is converted into water, chlorine, nitrogen, protoxide of nitrogen, and an acid hydrochlorate of ammonia.

This salt is not found in nature. It may be readily obtained by adding carbonate of ammonia to chloric acid to complete saturation, and then evaporating the liquor. The evaporation should be very carefully conducted; indeed it should be in a manner spontaneous, to prevent the volatilization of the salt. It is of no use in the arts.

REFERENCES. *Vauquelin's description of Chlor. of Amm. Ann. de Chim.* xcv̄. 96. *Ann. of Phil.* vii. 39.

Iodate of Ammonia.—Forms small indeterminate crystals; when heated is decomposed into oxygen, nitrogen, water and iodine; when heated in close tubes, the tubes are frequently burst; but Gay Lussac succeeded in collecting the products, which were equal volumes of oxygen and nitrogen gases. He states its composition to be 100 acid and 10·94 ammonia, or two volumes gaseous ammonia, one volume iodine and two and a half volumes oxygen.— *Thenard, Traité de Chim.*

This salt may be obtained by adding ammonia to iodic acid to saturation, small crystals being immediately deposited.

Hydrochlorate or Muriate of Ammonia—Atom. Num. 52·45—*Symb.*
$(3H+N)+(Cl+H)$—*Sp. gr.* 1·45 water$=1$.

Known in commerce as *Sal-Ammoniac*, a name given to it by the ancients, because it was found in great quantities near the temple of Jupiter Ammon.

Crystallizes ordinarily in long needles, which appear to be hexahedral pyramids; white, of a very sharp taste; soluble in three parts of water at 60°, and in equal parts of boiling water; exposed to heat, it melts in its own water of crystallization, dries and sublimes in the

form of white vapours; is decomposed by the fixed alkalies and alkaline earths; reddens litmus paper, [*Berzelius*]; calcined with carbonate of lime, it yields solid chloride of calcium, volatile carbonate of ammonia and water.

PREPARATION AND NATIVE STATE. Hydrochlorate of ammonia is found native in the dung of certain animals, particularly the camel; and in human urine. It appears also to exist in small quantities in the vicinity of volcanoes, and Dr. Marcet has ascertained that it exists in sea water, and may be separated by sublimation from the uncrystallizable part, called *bittern.—Phil. Trans.* 1822. 454.

This salt may be formed directly, by mixing over mercury equal measures of ammoniacal gas, and muriatic acid gas, which are entirely condensed into a white solid.

The common sal-ammoniac of the shops is prepared by a circuitous process from an impure carbonate of ammonia, obtained from the distillation of bones and other animal matters. This carbonate of ammonia, by being kept in contact with sulphate of lime and water, is converted into sulphate of ammonia. This again is decomposed by muriate of soda, which affords muriate of ammonia and sulphate of soda. The latter salt is separated by priority of crystallization, and the muriate of ammonia is then purified by being once or twice sublimed. In this way it is usually obtained in the form of a hard elastic cake. Sulphate of ammonia is also obtained by decomposing with sulphuric acid the hydrosulphate and hydrocyanate of ammonia which is collected in the manufacture of coal gas; or by lixiviating the soot of coal.

USES. This salt is employed to furnish ammonia and the carbonate of ammonia; in certain metallurgic operations; in tinning the surface of copper to prevent its oxidation: it is employed also in small quantities in dyeing; in medicine as a stimulant, and when dissolved in nitric acid, forms the *aqua regia* of commerce, employed for dissolving gold, instead of a mixture of nitric and muriatic acids.

ACTION ON THE ANIMAL ECONOMY. This salt is poisonous when taken into the stomach, or applied in large quantities to wounds. It causes vomiting, convulsions and death.—*Beck's Med. Juris.*

REFERENCES. *Sal-ammoniac and its manufacture, Encyc. Britannica Suppl. A volcanic product in Central Tartary, Brande's Jour.* x. 197. *Astley, improvements in the manufacture of, Repert. of Arts,* 2d ser. xii. 248. *Manufacture of, in Egypt, Clarke's Trav.* v. 23. *Parkes' Chem. Essays,* iv. *on Sal-ammoniac.*

Hydrobromate of Ammonia.— A white anhydrous salt, which by solution and evaporation may be obtained in four-sided prisms. It may be formed by similar processes as the hydriodate.

*Hydriodate of Ammonia.—*Crystallizes in cubes, which are more soluble than sal-ammoniac, and nearly as volatile, subliming in close vessels without decomposition. It may be obtained by combining directly, equal volumes of hydriodic acid and ammonia in their gaseous state; or by saturating liquid hydriodic acid with carbonate of ammonia.

Hydrofluate of Ammonia.—Crystallizes with much difficulty; has a very sharp taste; when heated, disengages a portion of ammonia, passes to an acid state and vaporizes under the form of dense and very disagreeable white fumes, at a temperature scarcely above that of boiling water; is very soluble in water; is decomposed by sulphuric acid with brisk effervescence and a great disengagement of heat.

This salt may be prepared by adding a solution of ammonia to the hydrofluoric acid, allowing a slight excess of ammonia, and afterwards evaporating the liquor at a moderate heat in a platinum or silver vessel.

REFERENCES. *Gay Lussac and Thenard, Jour. de Phys. January,* 1809. *Repert. of Arts,* 2d ser. xv. 90. *J. Davy, Repert. of Arts,* 2d ser. xxii. 77.

Nitrate of Ammonia—Atom. Num. 71— *Symb.* (3H+N)+(5O+N.)

Known by the older chemists under the name of *Nitrum Flammans.*

Crystallizes in various forms according to the manner in which its solution has been evaporated; if at a temperature below 100° F. in six-sided prisms, terminated by six-sided pyramids; if boiled down its crystals are thin and fibrous; and when the evaporation is carried so far that the salt immediately concretes on a glass rod in cooling, it then forms a compact and shapeless mass; is deliquescent, (except when evaporated at a high temperature,) and soluble in twice its weight of water at 60°; has an acrid and bitter taste; undergoes watery fusion when exposed to heat, giving off its water of crystallization, and a small portion of its alkali; when gently heated in a retort is converted into water and the protoxide of nitrogen; when thrown into a red hot crucible or heated to the temperature of 600° it inflames or explodes, and the products are water, nitrogen and the deutoxide of nitrogen, the inflammation being produced, according to Thenard, by the rapid combination of the oxygen of the nitric acid with the hydrogen of the ammonia.

The composition of this salt varies according to the mode of its preparation.—*Davy.*

PREPARATION. This salt has not been found native. It may be procured by the direct union of ammonia with nitric acid; or more easily by saturating dilute nitric acid with carbonate of ammonia, and evaporating the solution until a pellicle appears on the surface. The only use to which it is applied is in the process for obtaining protoxide of nitrogen.

SECTION III.

SULPHUR.

Atom. Num. 16—*Symb.* S—*Sp. gr.* 1·99 water = 1.

This substance has been known from the most remote periods of antiquity. It is met with under two different forms; a compact solid, which has generally the shape of long rolls or sticks, called *roll brimstone;* and a light powder called *flowers of sulphur.*

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PROPERTIES. Sulphur is a brittle solid of a light yellow colour, has little taste, but when rubbed emits a peculiar odour. It is a non-conductor of electricity, and is excited negatively by friction. When exposed to heat it melts at the temperature of 216° or 220° F.; between 230° and 280° F., it possesses the highest degree of fluidity, and it is then of an amber colour; when heated to about 320° it begins to thicken, and acquires a reddish tint; and at temperatures between 428° and 482° it is so tenacious that the vessel may be inverted without any sulphur falling out. From 482° to its boiling point, it again becomes liquid, but never to the same extent as when at 248°. At 550° to 600° F. it volatilizes rapidly and condenses again unchanged in close vessels, although it begins to rise slowly in vapour even before it is completely fused.

Sulphur may be crystallized.—The crystalline arrangement is generally perceptible in the centre of a common roll of sulphur; and by some management, regular crystals may be obtained. To attain this end, several pounds of sulphur should be melted in an earthen crucible; and when partially cooled, the outer crust should be pierced, and the crucible quickly inverted, so that the inner, and as yet fluid parts, may gradually flow out. On breaking the solid mass, when quite cold, crystals of sulphur will be found in its interior.

M. Mitscherlich has made the discovery of two primary forms of sulphur. The one, which occurs in nature, is an octahedron, with a rhombic base; the other, produced by the slow cooling of fused sulphur, is an oblique rhombic prism. According to Dumas, the sulphur obtained by the evaporation of a solution of sulphur in the carburet of sulphur, crystallizes like the native.

Liquified sulphur suddenly cooled, is variously affected, according to its temperature.—When the most fluid sulphur is suddenly cooled, it becomes brittle, but the thickened sulphur, similarly treated, remains soft, and more soft as the temperature has been higher. Thus at 230° sulphur is very liquid and yellow, and cooled suddenly by immersion in a large quantity of water, it becomes yellow and very friable; at 374°, it is thick and of an orange colour, and by cooling, becomes at first soft and transparent, but soon friable and of the ordinary appearance; at 428° it is red and viscid, and when cooled, soft, transparent, and of an amber colour; and at the boiling point it is of a deep brown red colour, and when cooled, very soft, transparent, and of a red brown colour.—*Dumas, Ann. de Ch. et de Ph.* xxxv. 83.

Solubility of sulphur.—Sulphur is completely soluble in boiling oil of turpentine, which is one of the tests of its purity. It is also soluble in alcohol, if the two bodies are brought into contact when both are in a state of vapour. On pouring this compound into water, the sulphur will be precipitated. [For a description of the details of the process, see *Henry's Chem.* i. 404.]

Presence of hydrogen in sulphur.—The presence of hydrogen in sulphur, first inferred by M. Berthollet, jun. has been satisfactorily proved by the experiments of Sir H. Davy. By exposing sulphur to the strong heat of a powerful galvanic battery, he found that sulphuretted hydrogen was disengaged. But the quantity was so small that he was led to consider it nothing more than an accidental ingredient. This view of the subject is also embraced by Berzelius.—*Ann. de Chim.* lxxix. 119.

Milk of sulphur, or *precipitated sulphur* of the pharmacopeia, some-times used for medicinal purposes, is formed by precipitating sulphur from some of its alkaline solutions, as from the hydro-sulphuret of po-tassa, by an acid. When washed and dried, it is in the form of a yellow-ish-grey impalpable powder, and is considered, by Dr. Thomson, as a compound of sulphur and water.

PREPARATION AND NATIVE STATE. Sulphur is found native in large quantities in the vicinity of volcanoes, and as an article of commerce is chiefly brought from Sicily. It is also abundant in combination in a vast number of native sulphurets and sulphates. Among the most important of these are the sulphurets of iron, lead, mercury, antimony, copper and zinc.

This substance is prepared artificially by being separated from the earthy substances with which it is combined, in the neighbourhood of volcanoes, or from the compounds which it forms with iron, copper, &c. In the former case it is exposed to heat, in large pots, well cov-ered to prevent the admission of air; when fluid, the impurities fall to the bottom, and it is then poured into moulds, thus forming the cylin-ders. When further purification is necessary a greater heat is applied and the sulphur is sublimed, the process being conducted in pots hav-ing receivers adapted to them, in which the vapour is condensed. In the latter case the sulphurets are roasted and the fumes received into chambers of brick work, where the sulphur is gradually deposited; it is then purified by fusion and cast into sticks. In this state it is known in commerce by the name of *roll brimstone;* when it is further puri-fied by sublimation, it is called *sublimed sulphur*, or *flowers of sul-phur*.

USES. Sulphur is extensively employed in the manufacture of sul-phuric acid; in that of gunpowder, &c. When heated to 300° or 350° F. and poured, at that temperature, into water, it becomes tenacious like wax, and may be applied, [as was done by Mr. Tassie,] to take im-pressions from engraved stones, seals, &c. It is also used for cement-ing iron bars in stone.

In medicine sulphur is employed both as an external application and as an internal remedy, especially in diseases of the skin.

IMPURITIES.—Sulphur sometimes contains earthy impurities, which can be readily ascertained by heating it on a piece of platinum leaf— when the sulphur will evaporate and leave the earthy substances. Pure sulphur also is perfectly soluble in boiling oil of turpentine.

Sometimes arsenic is found in sulphur. According to M. M. Geiger and Reimann the minutest quantity can be detected as follows: A cer-tain quantity of precipitated sulphur, flowers of sulphur, or ordinary sulphur finely pulverized, is to be digested with ammonia for a con-siderable time, then filtered, and afterwards the clear liquid acted upon by muriatic acid in excess. If a yellow precipitate occurs, it is an in-dication of the presence of arsenic; if not, the liquid is to be evapora-ted until only a few drops remain. A little ammonia is then to be added; afterwards a small quantity of muriatic acid; and finally a little solution of sulphuretted hydrogen. If there be the smallest quan-tity of arsenic, it will be rendered evident by a yellow precipitate.— *Brande's Jour. N. S.* v. 192.

SULPHUR AND OXYGEN.

Chemists are at present acquainted with four compounds of oxygen and sulphur, all of which have acid properties. Their composition is shown in the following table.

					S. O.
Hypo-sulphurous acid,	.	.	.	.	$32+16=48$
Sulphurous acid,	.	.	.	.	$16+16=32$
Hypo-sulphuric acid,	.	.	.	.	$32+40=72$
Sulphuric acid,	.	.	.	.	$16+24=40$

Hyposulphurous Acid—Atom. Num. 48,—Symb. $2O+2S$.

This acid may be formed by digesting sulphur in a solution of any sulphite, or by transmitting a current of sulphurous acid into a solution of sulphuret of calcium or strontium. In the former case, the sulphurous acid takes up an additional quantity of sulphur, and a salt of hyposulphurous acid is obtained; and in the latter, the sulphurous acid gives part of its oxygen to the metal, and its remaining oxygen unites with the sulphur. It is not easy to procure this acid in a free state, as it is almost immediately decomposed by the reaction of its elements when detached from the base with which it is combined.

The compounds of this acid with bases are called *Hyposulphites.* They are mostly soluble in water, and have a bitter taste. The solution precipitates the nitrates of the oxides of silver and mercury black, as sulphurets of the metals; and salts of baryta and oxide of lead are thrown down as white insoluble hyposulphites of those bases. The solution of all the neutral hyposulphites has the peculiar property of dissolving recently precipitated chloride of silver in large quantity, and forming with it a liquid of an exceedingly sweet taste.

It appears from the experiments of Rose, that although the ratio of the elements of hyposulphurous acid is as 16 to 8, the atom of the acid or the quantity required to neutralize one atom of an alkali, is not 24, but 48; and hence that its smallest molecule must be formed of two atoms of sulphur united with two atoms of oxygen.

REFERENCES. *Thomson's Inorganic Chemistry. Herschel, in Edin. Phil. Jour.* i. 8, 396.

Sulphurous Acid—Atom. Num. 32—*Symb.* $2O+S$—*Sp. gr.* 2.222 air =1.

This acid appears to have been known at a very early period, though first distinguished as a separate substance by Stahl. It was also obtained and examined by Priestley in 1774, and has since been accurately analyzed by Gay Lussac and Berzelius.

PROPERTIES. A gaseous and invisible acid; has a sour taste and a pungent suffocating odour; extinguishes burning bodies without being itself inflamed; is fatal to animal life, producing a violent spasm of the glottis, by which the entrance of the gas into the lungs is prevented, and, even when diluted with air, excites cough and causes a peculiar uneasiness about the chest; slightly reddens litmus paper, and then slowly bleaches it; destroys most vegetable colours; is absorbed by water to the extent of 33 times its bulk; is readily liquified by compression; by combination with bases it forms *Sulphites.*

It discharges vegetable colours.—Vegetable blues are reddened by sul-

phurous acid previous to their being discharged. This effect may be illustrated in a striking manner by holding a red rose over the blue flame of a common match, by which the colour will be discharged wherever the sulphurous acid comes in contact with it, so as to render it beautifully variegated, or entirely white. It is remarkable that the colouring principle is not destroyed; for it may be restored either by a stronger acid or by an alkali. As the bleaching powers of this acid are quite considerable, it is much used in whitening silk and straw work. It also removes fruit stains from woollen cloth.

It has a very strong attraction for oxygen——Though sulphurous acid cannot be made to burn by the approach of flame, it has a strong attraction for oxygen, uniting with it under favourable circumstances, and forming sulphuric acid. The presence of moisture is essential to this change. A mixture of sulphurous acid and oxygen gases, if quite dry, may be preserved over mercury, for any length of time, without acting on each other. But if a little water be admitted, the sulphurous acid gradually unites with oxygen, and disappears entirely. For this reason, a solution of sulphurous acid in water cannot be kept, unless atmospheric air be carefully excluded. Many of the chemical properties of sulphurous acid are owing to its affinity for oxygen. On being added to a solution of the peroxide of iron, it takes oxygen, and thus converts the peroxide into the protoxide of that metal. The solutions of metals which have a weak affinity for oxygen, such as gold, platinum and mercury, are completely decomposed by it, those substances being precipitated in the metallic form. Nitric acid converts it instantly into sulphuric acid, by yielding some of its oxygen. The peroxide of manganese causes a similar change, and is itself converted into the protoxide of manganese, which unites with the sulphuric acid.

It is absorbed by water.—To show how readily this gas is absorbed by water, let a small bottle be filled with it over mercury and place the thumb on the mouth of the bottle and take it off under water. This fluid will instantly combine with it, and be forced up into the bottle with explosive violence by the pressure of the atmosphere. Water may be easily impregnated with sulphurous acid gas by passing it in a current through this fluid ; for which purpose the best mode is to employ the series of bottles well known by the name of Woulfe's apparatus. From the solution, when recently prepared, the gas may be separated by heat, but not by congelation.

It is readily liquified by compression.—Of all the gases, sulphurous acid is most readily liquified by compression. According to Mr. Faraday, it is condensed by a force equal to the pressure of two atmospheres. M. Bussy has obtained it in a liquid form under the usual atmospheric pressure, by passing it through tubes surrounded by a freezing mixture of snow and salt. The *Anhydrous Liquid Acid* has a density of 1·45. It boils at 14° F. From the rapidity of its evaporation at common temperatures, it may be used advantageously for producing an intense degree of cold. M. Bussy succeeded in freezing mercury, and liquifying several of the gases, by the cold produced during its evaporation.—*Ann. of Phil.* xxiv. 307. *Faraday, Phil. Trans. for* 1823, *and Ann. of Phil.* xxiii. 93.

M. de la Rive has recently discovered a *solid* compound of sulphurous acid and water, procured by passing moist sulphurous acid gas through a recipient, cooled down to the temperature of from 5° to 14° F. Colourless crystals, of an acid and not unpleasant taste, are con-

densed on the inner side of the vessel. This compound is also formed during the evaporation of liquid sulphuric acid; in this case the moisture of the atmosphere contributes to its formation; but it is then mixed with ice.—*Berzelius, Traité de Chim.* ii. 25.

PREPARATION AND NATIVE STATE. Sulphurous [acid is found native only in volcanic countries, and most generally issuing from the fissures of lava. It is constantly disengaged from the Solfatera near Naples, from the summit of Stromboli, &c. It is also found in certain hot springs near volcanoes in Italy.

It may be artificially prepared in either of the following ways.

1. By burning sulphur at a low temperature, in common air, under a bell glass—or by burning sulphur in dry oxygen gas, in which case it is the sole product of the combustion.

2. By depriving sulphuric acid of one atom of its oxygen, which may be done, by mixing with it sawings of wood, powdered charcoal or other vegetable matters, in a retort, and applying heat. But the best method of obtaining pure sulphurous acid is by putting two parts of mercury and three of sulphuric acid into a glass retort, the beak of which is received under mercury, and heating the mixture by a lamp. In this case each atom of sulphuric acid decomposed loses one atom of oxygen, which combines with the metallic mercury, and the rest of the oxygen comes away in the form of sulphurous acid gas. The oxide of mercury thus formed, combines with another portion of sulphuric acid not decomposed.

Sulphurous acid may be collected without a mercurial trough, by displacement in the manner shown in the annexed figure. A tube twice bent at right angles is fixed at one end to a common flask with plaster-of-paris, while the other end is put into a bottle so as to touch the bottom. The sulphuric acid and mercury being now put into the flask, heat may be applied by a spirit lamp. The heavy sulphurous acid gas shortly displaces the air in the bottle, which when filled is corked till it is required for experiment, covering it with a little gas lute, if it is intended

to keep it for any length of time before using it.—*Reid's Practical Chemistry.*
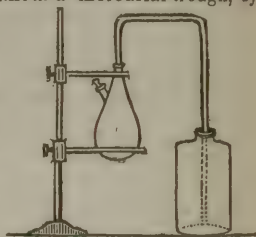
USES. Sulphurous acid prepared by the combustion of sulphur, is much used for bleaching cotton goods, and also for whitening silk, wool and straw. In wine countries it is sometimes used to check vinous fermentation. In medicine it is employed in some diseases of the skin.

REFERENCES. *Parkes' Chem. Essays, art. Bleaching. For cases illustrating its action on the Animal Economy, see Beck's Medical Juris.* 6th edit. *Dumas describes and figures several varieties of apparatus employed in the hospitals of Paris, for the application of gaseous sulphurous acid—Traité de Chim. &c.*

Hyposulphuric Acid,—Atom. Num. 72—*Symb.* 5O+2S.

Discovered by Welter and Gay Lussac, in 1819.—*Ann. de Chim. et de Phys.* x. 312.

PROPERTIES. A colourless liquid, without odour even in the greatest state of condensation, by which circumstance it is distinguished from sulphurous acid; reddens litmus; has a sour taste, and forms neutral salts with the alkalies; cannot be obtained free from water; its solution, if confined with a vessel of sulphuric acid, under the exhausted receiver of an air pump, may be concentrated till it has a density of 1·347, but if an attempt is made to condense it still further, the acid is decomposed, sulphurous acid gas escapes, and sulphuric acid remains in solution, a similar change being still more readily produced if the evaporation is conducted by heat.

PREPARATION, The process recommended by Welter and Gay Lussac for obtaining this acid, is to pass a current of sulphurous acid gas through water containing peroxide of manganese in fine powder. The manganese yields oxygen to the sulphurous acid, thus converting one part of it into sulphuric, and another part into the hyposulphuric acid, both of which unite with the protoxide of manganese. To the liquid, after filtration, a solution of pure baryta is added in slight excess, which precipitates the protoxide of manganese, and forms an insoluble sulphate of baryta with the sulphuric, and a soluble hyposulphate with the hyposulphuric acid. The hyposulphate of baryta is then decomposed by a quantity of sulphuric acid exactly sufficient for precipitating the baryta, and the hyposulphuric acid is left in solution. This solution is then concentrated by evaporation, until its density approaches 1·347.

REFERENCES. *Welter and Gay Lussac, on Hyposulphuric Acid and Hyposulphates, Ann. of Phil.* xiv. 352.

Sulphuric Acid.—Atom. Num. 40—*Symb.* 3O+S.

This acid has been known ever since the time of Basil Valentine, who appears to have discovered it about the close of the fifteenth century.

Sulphuric acid exists in two states:—1st, a dry crystalline solid, such as is obtained from the sulphuric acid of Nordhausen; 2d, a liquid combined with a certain proportion of water, such as it ordinarily exists and as it is used in the arts, and in the laboratory. I shall notice each of these separately.

Anhydrous Sulphuric Acid.—Sometimes called Glacial or Fuming Sulphuric Acid.

PROPERTIES. A white and opake solid; liquifies at 66° F. and then has a specific gravity of 1·97, and boils at a temperature between 104° and 122°, forming, if no moisture is present, a transparent vapour; when exposed to the air unites with watery vapour, and flies off in the form of dense white fumes; is very caustic and reddens litmus powerfully; dissolves sulphur and becomes of a brown, green or blue colour, and upon the addition of water, the sulphur is deposited and the acid is converted into ordinary sulphuric acid; dissolves indigo

with great readiness, the solution assuming a most beautiful purple colour, and hence it is much employed for this purpose.

PREPARATION. This acid is obtained from a peculiar kind of hydrous sulphuric acid, manufactured at Nordhausen, a small vilage in Germany, by the distillation of the protosulphate of iron. Gmelin has procured it during the rectification of common sulphuric acid, by changing the receiver at the moment when it is filled by opake vapours, and surrounding the fresh receiver with ice.—[*Ann. de Chim. et de Phys.* xxxii. 223.] Professor Mosander, of Stockholm, proposes the following very simple mode of preparing it. If the oxide of antimony be treated with excess of sulphuric acid till the oxide is saturated, and the excess of acid then driven off by a low temperature, the sulphate is obtained dry and crystallized. If this salt be put into a retort and heated to dull redness, the greater part of the acid is driven off in an anhydrous state and is easily condensed in a cool receiver.—*Johnston's Report. On this acid see also Thomson's First Prin ; Bussy, in Ann. of Phil.* xxiv. 259, *and Repert. of Arts,* 2d ser. xlvi. 181.

Hydrous Sulphuric Acid—Oil of Vitriol.

PROPERTIES. A colourless, dense, oily fluid, one of the strongest acids with which chemists are acquainted; is powerfully corrosive; decomposes all animal and vegetable substances by the aid of heat, causing deposition of charcoal and formation of water; has a sour taste, and reddens litmus though greatly diluted with water; boils at 620° F. and has a specific gravity, in its most concentrated form, of 1·847, or a little higher, never exceeding 1·850; has a great affinity for water, uniting with it in every proportion, and producing, during the combination, an intense heat; absorbs watery vapour with avidity from the air, and on this account is employed in the process for freezing water by its own evaporation ; freezes at — 15° F. but when diluted with water, so as to have a specific gravity of 1·78, it congeals even above 32° F. and remains in the solid state, according to Mr. Keir, till the temperature rises to 45° F. but when mixed with rather more than its weight of water, has its freezing point lowered to — 36° F.

Sulphuric Acid chars animal and vegetable substances.—Hence the acid is apt to acquire a brown tinge, from particles of straw, resin or other matter that may accidentally have fallen into it. Its operation in this case, as well as in destroying the texture of the skin, and in forming others, is supposed to be owing to its affinity for water.

It has a great affinity for water.—When this acid is suddenly mixed with water, a considerable degree of heat is produced. Four parts, by weight, of concentrated sulphuric acid, and one of water, when mixed together, each at the temperature of 50° F. have their temperature raised to 300°. The greatest elevation of temperature, Dr. Ure finds to be occasioned by the sudden mixture of 73 parts, by weight, of strong sulphuric acid with 27 of water. A diminution of bulk also ensues ; one measure of acid and one of water not occcupying the space of two measures, but about 1-17th less.

It takes moisture from the air, even at a boiling temperature, when it is concentrated ; and hence it cannot be concentrated so well in an open as in a close vessel, on which account retorts of glass or platinum, are used for the last stage of its concentration by the manufacturers.

Though sulphuric acid, when mixed with water as in the above cases, produces a high degree of heat, a mixture of 2 parts of acid and 3 of snow reduces the mercury in Fahrenheit's thermometer to — 23°. Hence this is employed as a freezing mixture. To explain these results, which at first appear contradictory, it is sufficient to observe : 1st, that snow or ice, in passing from the solid to the liquid state, absorbs caloric ; and, 2d, that sulphuric acid, in combining with water, gives out caloric ; hence either heat or cold is produced according as water is employed in the liquid or solid form.

Many of the simple non-metallic combustibles decompose sulphuric acid, when assisted by heat.—When hydrogen gas and sulphuric acid are made to pass through a red hot porcelain tube, the acid is completely decomposed, and there results water, sulphurous acid or sulphur, according as the proportion of hydrogen to the acid is greater or less.— When the hydrogen is in excess, and the heat is not too high, sulphuretted hydrogen is also produced. Sulphuric acid is also decomposed by carbon, phosphorus and sulphur.

PREPARATION AND NATIVE STATE. The occurrence of this acid in an uncombined state is very rare in nature ; and it is probable, as Thenard suggests, that naturalists have often mistaken for it an acid sulphate.—(*Traité de Chim.*) It is, however, found nearly pure, though much diluted with water, in Byron, Genessee County, N. Y.—(*New York Geological Reports for* 1838.) In combination with various bases, as lime, potassa, soda, &c. this acid is extremely abundant.

The process for forming sulphuric acid, at present very generally adopted, is by burning sulphur, previously mixed with one-eighth of its weight of nitrate of potassa. The mixture is burned in a furnace so contrived that the current of air which supports the combustion, conveys the gaseous products into a large leaden chamber, the bottom of which is covered, to the depth of several inches, with water. The nitric acid yields oxygen to a portion of sulphur, and converts it into sulphuric acid, which combines with the potassa of the nitre ; while the greater part of the sulphur forms sulphurous acid, by uniting with the oxygen of the air. The nitric acid, in losing oxygen, is converted into the deutoxide of nitrogen, which, by mixing with air at the moment of its separation, gives rise to the nitrous acid vapours. The gaseous substances present in the leaden chamber are, therefore, sulphurous and nitrous acids, atmospheric air and watery vapour. And it appears that the sulphurous is converted into the sulphuric acid, by the oxygen of the air, and that the combination is not effected directly, but through the medium of the nitrous acid. For details of this explanation see Davy's Elements and Webster's Brande. An account of the successive improvements in the manufacture of sulphuric acid, will be found in Parkes' Chemical Essays. Mr. Reid, in his Practical Chemistry, describes an apparatus which illustrates in a very happy manner the theory of the formation of this acid.

Although sulphuric acid, as ordinarily prepared, answers in general the purpose of the artist, it is never quite pure. It contains some sulphate of potash and of lead, the former derived from the nitrate employed in making it, the latter from the leaden chamber. To separate these impurities, the acid should be distilled from a glass or platinum retort. The former may be used with safety, by putting some fragments of platinum leaf into it, which causes the acid to boil free-

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ly on the application of heat, without danger of breaking the vessel.—
Faraday, Chem. Manip. sect. 409.

The strength of sulphuric acid is best judged of by saturating a
known quantity with an alkali, and it may be assumed as sufficiently
correct, that 100 grains of dry sub-carbonate of soda neutralize 92
grains of pure liquid sulphuric acid ; or that 100 grains of the acid
require 108 or 108·5 of the sub-carbonate for saturation.   The strength
may also be judged of by its specific gravity.   Mr. Dalton has publish-
ed a table, exhibiting the specific gravity and boiling point of acid of
various strengths.—*New System of Chem. Philosophy.   See also Henry's
Chem.*

ADULTERATION.   The presence of sulphuric acid may always be de-
tected by the white insoluble precipitate which it forms when added to
any soluble salt of baryta.   If the acid is coloured, it indicates the pre-
sence of organic matter.   If, when diluted with water, it becomes tur-
bid, we may infer the presence of sulphate of lime, sulphate of lead or
some such salt.   But the amount and nature of these impurities may
be more satisfactorily determined by heating a portion of acid in a
platinum spoon ; the pure acid will be entirely volatilized, but the salts,
if it contain any, will remain, and may be subsequently examined.

According to Vogel, the English sulphuric acid contains arsenic in
the form of arsenious acid.   Hence if a current of sulphuretted hydrogen
is passed through a portion of this acid diluted with from four to six
parts of water, an orange yellowish precipitate of the sulphuret of
arsenic is thrown down.— *Lond. and Edin. Phil. Mag. &c.* vii. 235.

USES.   The uses of sulphuric acid are very numerous.   1. It is that
by means of which we obtain almost all the other acids employed in
the laboratory or in the arts.   2. To extract soda from common salt.
3. In the manufacture of alum, sulphate of iron ; to dissolve indigo;
in the manufacture of chlorine, and in various chemical processes.
Indeed it is one of the most common agents employed by chemists and
artists.

REFERENCES.   *On the modes of manufacturing Sulphuric Acid, see
Chaptal's Chemistry, applied to the Arts,* iii. 21 ; *Parkes' Chemical Essays,
and Dumas' Traité de Chim., &c.*

SULPHUR AND CHLORINE,

Chloride of Sulphur.—Atom. Num. 51·45—*Symb.* Cl+2S—*Sp. gr.*
1.687 water=1.

This compound was discovered by Dr. Thomson in 1804, and was
subsequently examined by Berthollet, Davy and Dumas.

PROPERTIES.   A liquid appearing red by reflected and yellowish-green
by transmitted light ; volatile below 200° F., and condenses again
without change on cooling ; emits acrid fumes when exposed to the
air, which irritate the eyes powerfully, and have an odour somewhat
resembling sea-weed, but much stronger ; does not redden dry litmus
paper, nor does it unite with the alkalies ; boils readily when heated in a
retort, but is not changed ; acts with energy on water, mutual decom-
position ensues, the water becomes cloudy from the deposition of sul-
phur, and a solution is obtained, in which muriatic, sulphurous, and
sulphuric acids, may be detected.

PREPARATION. Chloride of sulphur may be most conveniently prepared by passing a current of chlorine gas over flowers of sulphur gently heated. Direct combination takes place, and the product is obtained under the form of a liquid as above described.

Berzelius describes two compounds of chlorine and sulphur. One of which he calls *Chlorure sulfurique* ; the other, *Chlorure sulfureux.*

REFERENCES. *Thomson on the composition of Chloride of Sulphur, Ann. of Phil.* xv. 403. *Berzelius, Traité de Chim.* 1. 283.

SULPHUR AND BROMINE.

Bromide of Sulphur.

On pouring bromine on sublimed sulphur, combination ensues, and a fluid of an oily appearance and reddish tint is generated. In odour it somewhat resembles chloride of sulphur, and like that compound emits white vapours when exposed to the air, but its colour is deeper. It reddens litmus paper faintly when dry, but strongly if water is added. Cold water acts slowly upon the bromide of sulphur ; but at a boiling temperature, the action is so violent that a slight detonation occurs, and three compounds, hydrobromic and sulphuric acids, and sulphuretted hydrogen are formed. The formation of these substances is of course attributable to decomposition of water, and the union of its elements with bromine and sulphur. Bromide of sulphur is likewise decomposed by chlorine, which unites with sulphur, and displaces bromine.— *Turner.*

SULPHUR AND IODINE.

Iodide of Sulphur.

This compound is formed by heating gently four parts of iodine with one of sulphur. The product has a dark colour and radiated appearance like sulphuret of antimony. It decomposes with facility when exposed to a temperature a little more elevated than that at which it is formed, the iodine separating in the form of vapour.

This compound was first described by Gay Lussac.—*Ann. de Chim.* xci.

SULPHUR AND HYDROGEN.

According to some chemists, these substances combine in two proportions, forming what were originally termed *Sulphuretted Hydrogen* and *Supersulphuretted Hydrogen.* But the nature of the latter has not been clearly settled. Both, however, are allowed to possess acid properties, and some German chemists have proposed for the former the name of *Hydrothionic Acid.* This is preferable to the name of *Hydrosulphuric* acid, given to it by Gay Lussac, which would be more properly applied to liquid sulphuric acid. Should the supersulphuretted hydrogen prove to be a distinct substance, it may be called *Hydrothionous Acid.*

Hydrothionic Acid.—Atom. Num. 17—*Symb.*H+S—*Sp. gr.* 1·1805 air=1.

SYN. *Sulphuretted Hydrogen*, Scheele. *Hydrosulphuric Acid*, Gay Lussac. *Sulfide Hydrique*, Berzelius,

Discovered by Scheele in 1777.

PROPERTIES. A colourless gas, having a highly offensive taste and odour, similar to that of putrifying eggs or the water of sulphurous springs; is compressed into a liquid under a pressure of 17 atmospheres, at 50° F., resuming the gaseous state as soon as the pressure is removed; is very injurious to animal life; extinguishes all burning bodies, but the gas takes fire when a lighted candle is immersed in it, and burns with a pale blue flame; with oxygen gas forms a mixture which detonates by the application of flame or the electric spark; reddens litmus feebly, and forms salts with the alkalies called *Hydrosulphurets* or *Hydrosulphates*; is absorbed by water when agitated, or when recently boiled, from which the gas may be expelled without change; is partly decomposed when submitted to heat in a porcelain tube, a portion of sulphur and hydrogen separating, the first in a solid and the second in a gaseous state.

It is decomposed by Chlorine and Iodine.—Sulphuretted hydrogen is decomposed by chlorine and iodine in consequence of their great affinity for hydrogen, and the former is often employed as a means of purifying places which have been rendered noxious by this gas. The result of the action of chlorine is muriatic acid, that of the action of iodine, hydriodic acid.

It acts upon most of the metals.—Sulphuretted hydrogen acts upon most of the metals; the gas is decomposed, the sulphur combines with the metals, and the hydrogen is liberated. Hence it is used as a test of the presence of metals in solution.

It is absorbed by water.—Water when agitated or under pressure, absorbs three times its volume of this gas, forming a transparent and colourless liquid, with the taste and odour of the gas. But when exposed to the air, it becomes covered with a pellicle of sulphur. Sulphur is even deposited when the water is kept in closed bottles.

On the addition of a few drops of nitric or nitrous acid to the watery solution, sulphur is instantly precipitated. In this case the oxygen of the acid combines with the hydrogen of the gas, and the sulphur is separated. The gas itself, also, is decomposed when transmitted through sulphuric, nitric or arsenic acids. [*Brande's Jour.* ii. 152.] If a drachm of fuming nitric acid is poured into a bottle full of sulphuretted hydrogen gas, a bluish white flame passes rapidly through the vessel, sulphur and nitrous acid fumes make their appearance, and of course water is generated.

✱ *Liquid Sulphuretted Hydrogen.*—Mr. Faraday obtained sulphuretted hydrogen in a *liquid form* by producing it under pressure. It was then colourless, limpid and excessively fluid. Ether when compared with it in similar tubes, appeared tenacious and oily. It did not seem more consistant at 0° than at 45° F., and when raised from the former to the latter temperature, the only effect was, that part of the liquid rose in vapour, and its quantity diminished. When a tube containing it was opened under water, the liquid rushed immediately into gas, which when collected, had all the properties of sulphuretted hydrogen. The refractive power of the liquid appeared rather greater than that of water; it decidedly surpassed that of sulphurous acid. By a small gauge, introduced into the tube in which it was produced, the pressure of its vapour was nearly equal to 17 atmospheres at 50° F.— *Phil. Trans.* 1823, 192.

✱ *this is a test for the leads or other metals in wines.*

NATIVE STATE AND PREPARATION. Sulphuretted hydrogen is given off in small quantities from various springs denominated sulphureous. Also from many substances undergoing the process of putrefaction, as eggs, &c., and hence its peculiar odour can often be observed in the vicinity of sinks and sewers. Its presence can also be detected by its effects in blackening silver or other metallic substances.

This gas can readily be prepared by presenting sulphur to nascent hydrogen. Any of the sulphurets of the alkaline metals will furnish it by the mere addition of water. It may also be obtained by adding diluted sulphuric acid to sulphuret of iron; or more conveniently by heating bruised sulphuret of antimony in muriatic acid. It may be procured over water, though by agitation that fluid absorbs thrice its bulk. The use of metallic vessels should of course be avoided in procuring this gas.

TESTS. Sulphuretted hydrogen is readily distinguished from other gases by its odour. The most delicate chemical test of its presence is carbonate of lead (white paint,) mixed with water and spread upon a piece of white paper. So minute a quantity of sulphuretted hydrogen may by this means be detected, that one measure of the gas mixed with 20,000 times its volume of air, hydrogen or carburetted hydrogen, gives a brown stain to the whitened surface.—*Henry's Chem.* i. 467.

ACTION ON THE ANIMAL ECONOMY. Sulphuretted hydrogen is one of the most deleterious gases with which we are acquainted. According to the experiments of Dupuytren and Thenard, the presence of 1-1500th of sulphuretted hydrogen in air, is instantly fatal to a small bird; 1-800th killed a middle sized dog, and a horse died in an atmosphere which contained 1-250th of its volume. Chaussier has even proved that if this gas be made on the cutaneous surface of animals, it is sufficient to cause their death.— *Thenard, Traité de Chim. Jour. de Medicine, de M. Leroux, &c.*

USES. Sulphuretted hydrogen is used sometimes in medicine, as for example, in the form of baths, for certain cutaneous eruptions. It is also employed in the laboratory as a re-agent for detecting the presence of the metals.

REFERENCES. *This compound has been the subject of numerous researches by Berthollet, Chassier, Dupuytren, Davy, Gay Lussac and Thenard.—Berthollet has made it almost a complete study, Ann. de Chim. xxv. Chassier, Dupuytren and Thenard have examined its deleterious action upon the animal economy; Jour. de Medicine. Davy, Gay Lussac and Thenard, have examined its chemical properties; Recherches Physico Chimiques,* i.

Hydrothionous Acid.—Atom. Num. 33—Symb. H+2S.

SYN. *Supersulphuretted Hydrogen.*—Scheele. *Per-* or *Bi-sulphuretted Hydrogen.*

This substance was discovered by Scheele, afterwards examined by Berthollet, (*Ann. de Chim.* xxv.) and still more recently by Thenard. (*Ann. de Chim.* xlviii. 79, *or Johnston's Report.*) It may be conveniently made by boiling equal parts of recently slacked lime and flowers of sulphur, with five or six of water, when a deep orange yellow solution is formed, which contains a hydro-sulphuret of lime with excess of

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sulphur. On pouring this liquid into strong muriatic acid, a copious deposition of sulphur takes place ; and the greater part of the sulphuretted hydrogen, instead of escaping with effervescence, is retained by the sulphur. After some minutes, a yellowish semi-fluid matter like oil, collects at the bottom of the vessel, which is the bisulphuretted or super-sulphuretted hydrogen.

PROPERTIES. A viscid substance ; has the peculiar taste and odour of the sulphuretted hydrogen, but in an inferior degree ; unites with salifiable bases, forming salts, denominated, *Sulphuretted Hydrosulphurets*, (or *Hydrothionites*) ; is inflammable, and burns in the air with the smell of sulphurous acid ; when gently heated, is resolved into sulphur and sulphuretted hydrogen, and from the facility with which this decomposition is effected, the history of this substance is still imperfect.

The salts of the bi-sulphuretted hydrogen may be prepared by digesting sulphur in solutions of the alkaline or earthy hydro-sulphurets. They are also generated when alkalies or alkaline earths are boiled with sulphur and water. These salts absorb oxygen from the air, and pass gradually into hyposulphites. A similar change is speedily effected by the action of sulphurous acid. Dilute muriatic and sulphuric acids produce in them a deposition of sulphur, and evolution of sulphuretted hydrogen.

SALTS OF AMMONIA AND THE ACIDS CONTAINING SULPHUR.

Hyposulphite of Ammonia.—This salt has a pungent and excessively bitter taste ; it does not readily crystallize ; when heated it burns with a feeble flame and evaporates.—*Edin. Phil. Jour.* i.

Sulphite of Ammonia.—Crystallizes in six-sided prisms, terminated by six-sided pyramids, or in four-sided rhomboidal prisms, terminated by three-sided summits ; has a cool, penetrating and somewhat sulphurous taste ; is soluble in its own weight of cold water ; or in less than an equal weight of boiling water ; attracts moisture from the air, and rapidly passes to the state of a sulphate.

Though this salt usually contains water, it may be obtained anhydrous.—*Dobereiner in Phil. Mag. and Ann.* ii. 389.

Sulphate of Ammonia.—*Atom. Num.* 66—*Symb.* $(3H+N)+(3O+S)$ $+1Oq.$

SYN. *Secret Sal-Ammoniac,* Glauber.   *Vitriolated Ammoniac.*

PROPERTIES. Crystallizes usually in small six-sided prisms, whose planes are unequal, terminated by six-sided pyramids ; has a sharp and bitter taste ; is soluble in twice its own weight of water at 60° F. and in its own weight of boiling water ; when exposed to the air, slowly attracts moisture ; when heated, first decrepitates, then melts, and is converted into an acid sulphate ; at a red heat it is completely decomposed, nitrogen is disengaged, as well as water and the acid sulphate of ammonia which vaporizes in the form of a white cloud ; it is also decomposed by potassa, soda, &c.

PREPARATION AND NATIVE STATE. This salt is sometimes found native in the vicinity of volcanoes. In the laboratory it is obtained by adding excess of ammonia to dilute sulphuric acid, and evaporating the solution ; or by saturating dilute sulphuric acid by carbonate of ammonia,

or by decomposing muriate of ammonia by sulphuric acid. In the arts it is obtained in large quantities by treating sulphate of lime with the carbonate of ammonia, procured during the distillation of animal matter.

Hydrothionate of Ammonia.—Atom. Num. 34—*Symb.* (3H+N.)+
(H+S.)

Syn. *Hydrosulphuret of Ammonia. Hydrosulphate of Ammonia.*— Thenard.

Properties. When perfectly pure, this substance occurs in needle form crystals, which are transparent and colourless ; is very volatile, and when kept in a bottle, sublimes gradually to the top of the vessel, where it crystallizes in long transparent plates, by which means it is freed from any impurities which it may contain ; when exposed to the air it assumes a yellow colour, absorbs oxygen, and passes to the state of a hydroguretted sulphuret ; mixed with excess of ammonia, it dissolves speedily, and produces a considerable degree of cold.

Preparation. Pure hydro-sulphuret of ammonia may be obtained by combining ammoniacal gas and sulphuretted hydrogen gas at a low temperature. For details concerning the preparation of this compound see *Thenard, Traité de Chim.*

When sulphuretted hydrogen gas is passed through solution of ammonia, a substance is obtained which is commonly called *Liquid Hydrosulphuret of Ammonia ;* and which is much employed in the laboratory as a test. It is of a yellowish colour, and rapidly decomposes when exposed to the air or to heat.

Hydrothionate of Ammonia.

Syn. *Hydroguretted Sulphuret of Ammonia.*—Thomson and Thenard.

A liquid of the consistence of syrup, with a taste and odour similar to that of the hydrosulphuret of ammonia. But this, as well as the other compounds of this acid, is still imperfectly understood. See p. 161. And for further particulars, see *Thomson's or Thenard's Chemistry, and Herschel's paper, in Edin. Phil. Jour.* i. 13.

SECTION IV.

Phosphorus.

Atom. Num. 15·7—*Symb.* P—*Sp. gr.* 1·770 water= 1.

Phosphorus was discovered by Brandt, an alchemist of Hamburg, in 1669, but it was not until Scheele published his process for obtaining it, nearly a century afterwards, that it became sufficiently common to be accurately examined.

Properties. Phosphorus is transparent and almost colourless ; is so soft that it may be cut with a knife, and the cut surface has a waxy lustre ; is highly inflammable, undergoing a slow combustion, when exposed to the air at common temperatures ; fuses at the temperature of 108° F. ; and sublimes at 550° F., inflames spontaneously in chlorine ; when gently heated, burns very brilliantly in oxygen gas ; is soluble

in ether, alcohol, olive oil, &c. and communicates luminosity to these substances; decomposes nitrous acid, with combustion; is poisonous when taken into the stomach; by carefully fusing and cooling a large quantity it may be crystallized in rhombic dodecahedrons.—*Mitscherlich, in Phil. Mag. and Ann.* iii. 154.

Combustion of Phosphorus in air and in oxygen.—Phosphorus when brought into contact with air or oxygen gas at low temperatures, gives out white vapours and a peculiar alliaceous smell,—appears luminous in the dark, and is gradually consumed. Hence it should always be kept under water. If a stick of phosphorus be put into a jar of air inverted over water, the volume gradually diminishes, and if the temperature of the air is at 60° F. the whole of the oxygen will be withdrawn in the course of 12 or 24 hours. The residue is nitrogen, containing about 1·40th of its bulk of the vapour of phosphorus. It is remarkable that the slow combustion of phosphorus does not take place in pure oxygen, unless its temperature be about 80° F.; but if the oxygen be rarified by diminished pressure, or diluted with nitrogen, hydrogen or carbonic acid, then the oxydation occurs at 60° F. accompanied with the extrication of light and heat. The presence of certain gaseous substances, even in very small quantities, has been found by Mr. Graham, to have a remarkable effect in preventing the slow combustion of phosphorus.—*Jour. of Science, N. S.* vi. 83.

But though phosphorus, in a solid state, acts with very little energy upon oxygen gas, the case is different when the phosphorus becomes liquid—then it absorbs and solidifies this gas with great rapidity—and there results phosphoric acid, with much heat, and a very vivid disengagement of light. This may be shown by filling a small glass tube with mercury and introducing into it a small quantity of well dried phosphorus. The phosphorus, being lighter than the mercury, ascends to the upper part of the tube, where it may be melted by a small spirit lamp or piece of burning charcoal. Oxygen gas is now passed into the tube, bubble by bubble, each one on coming into contact with the phosphorus disappearing in an instant, and producing a flash of light, which the eye is scarcely able to support.—[*Thenard.*] This fact may also be shown by throwing some pieces of phosphorus in hot water, and then directing a stream of oxygen gas upon it.

Phosphorus is inflamed by the application of a very gentle heat.—According to Dr. Higgins, a temperature of 60° F. is sufficient to set it on fire when perfectly dry. It burns, when heated to about 148° F. with a very brilliant light, a white smoke, and a suffocating smell, and may be inflamed in an atmosphere rarified sixty times.

It may be set on fire by friction. Rub a very small bit between two pieces of brown paper, or of wood; the phosphorus will inflame and set the paper on fire also.

NATIVE STATE AND PREPARATION. Pure phosphorus does not exist in nature, but some of its acid compounds are found in combination with bases, especially in the form of phosphate of lime, which constitutes a large proportion of the solid matter of the bones of animals.

The process for obtaining phosphorus, now generally adopted, is, to ignite bones in an open fire, till they become quite white, so as to destroy all the animal matter they contain, and oxidize the carbon proceeding from its decomposition. The calcined bones, of which phosphate of lime constitutes nearly four fifths, should be reduced to a fine powder, and be digested for a day or two with half their weight of con-

centrated sulphuric acid, so much water being added to the mixture as to give it the consistence of a thin paste. The phosphate of lime is decomposed by the sulphuric acid, and two new salts are generated—the sparingly soluble sulphate and a soluble biphosphate of lime. On the addition of boiling water the biphosphate is dissolved, and may be separated, by filtration, from the sulphate of lime. The solution is then evaporated to the thickness of syrup, mixed with one fourth its weight of charcoal in powder, and heated in an earthen retort well luted with clay. The beak of the retort is put into water, in which the phosphorus, as it passes over in the form of vapour, is collected. When first obtained, it is frequently of a reddish-brown colour, owing to the presence of the phosphuret of carbon, which is generally formed during the process. It may be purified by being put into hot water, and pressed, while liquid, through chamois leather ; or the purification may be rendered still more complete by a second distillation.— *Turner.*

The principle on which phosphorus is prepared may be illustrated by mixing a small quantity of phosphoric acid or biphosphate of lime with half its weight of charcoal, and putting it into a green glass tube closed at one end, about a foot in length and half an inch in diameter. The tube should be coated with a mixture of clay and sand. It is then placed in a small furnace with a hole cut in the side, as in the annexed figure, and heated with a mixture of red hot cinders and charcoal. The phosphorus soon begins to come, condensing along the sides of the tube, and a flame appears at the open end, similar to what is produced by the combustion of phosphorus. If the tube is broken above the point where it is coated, after the gas ceases to be disengaged, on blowing through it, the phosphorus will immediately take fire and burn with a vivid light.—*Reid's Practical Chemistry.*
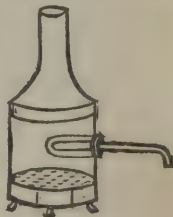
ACTION ON THE ANIMAL ECONOMY. Phosphorus is a violent and general excitant. In small doses its effects are very soon manifested, but are of short duration. In large doses it occasions death, by causing violent inflammation. Some physicians have administered it in solution in alcohol, ether and the oils ; others have recommended it in the form of pills. It is stated by Mr. Murray, that if phosphorus be allowed to stand in water for some time, it will render that fluid poisonous to animals that drink it.—*Ann. of Phil.* xvi. 232.

REFERENCES. *Lavoisier's Elements of Chem. Davy's Elements of Chem. Aikin's Chemical Dict. containing a detailed account of the various processes for obtaining Phosphorus, and of its action upon various substances. For the action of Phosphorus upon various mixtures of oxygen and other gases see Thenard,* i. 237. *Berzelius, Trait. de Chim.* i. 254. *For an account of the poisonous effects of Phosphorus, &c. see Beck's Med. Juris. Dr. Lobstein on Phosphorus.*

PHOSPHORUS AND OXYGEN.

The compounds of phosphorus and oxygen to be here described, are as follows.

				P. O.
Oxide of phosphorus,	.	.	.	47.1...8=55.1
Hypophosphorus acid,	.	.	.	31.4....8=39.4
Phosphorous acid,	.	.	.	15.7..12=27.7
Phosphoric acid, ⎱	.		.	15.7..20=35.7
Pyrophosphoric acid, ⎰				

Oxide of Phosphorus.—*Atom. Num.* 55·1—*Symb.* O+3P.

The white coating which forms upon the surface of phosphorus, when it is kept for some time under water, has been considered as an oxide of phosphorus; but from some experiments of Rose this seems to be nothing more than phosphorus in a peculiar mechanical state, which deprives it of its usual action upon light and renders it opaque. But the red particles which collect when a jet of oxygen is thrown upon phosphorus while in fusion under hot water, have been examined by M. Pelouze, and pronounced by him to be an oxide of phosphorus. The red matter left when phosphorus is rapidly burned is probably of the same nature.

The oxide of phosphorus is of a red colour, without taste or odour, and is insoluble in water, ether, alcohol, and oil; is permanent in the air even at 662° F. but takes fire at a low red heat; it takes fire in chlorine gas, and is rapidly oxidized by nitric acid; it does not possess any alkaline properties.—*Ann. de Chim. et de Phys.* 1. 83.

Hypophosphorous Acid.—*Atom. Num.* 39·4—*Symb.* O+2P.

This acid was discovered by M. Dulong, in 1816, and may be formed by the action of water upon the phosphuret of an alkaline metal, as phosphuret of barium. An insoluble precipitate is formed, from which the liquid is to be separated by filtration. To this solution sulphuric acid is carefully added so long as any precipitate is formed. The sour liquor which remains, after a second filtration, is to be concentrated by evaporation, when a viscid, uncrystallizable acid fluid will be obtained, to which the above name has been given.

It is still doubted, by some chemists, whether it may not be a triple compound of oxygen, phosphorus and hydrogen, or a *hydracid*, in which case its proper appellation would be *hydrophosphorous acid*.

REFERENCES. *Dulong, in Phil. Mag.* xlviii. 271. *Sir H. Davy, Phil. Trans.* 1818, *and Ann. of Phil.* xiii. 210. *Rose on the Salts of, Ann. de Chim. et de Phys. July,* 1828.

Phosphorous Acid.—*Atom. Num.* 27·7—*Symb.* 1½O+P.

Discovered by Sir H .Davy, in examining the action of proto-chloride of phosphorous upon water.

PROPERTIES. Phosphorous acid has a very sour taste, and smells somewhat like garlic; reddens litmus powerfully; is decomposed by heat, yielding the same products as the hypophosphorous acid; unites with bases and forms salts, which are termed *phosphites;* in solution it absorbs oxygen slowly from the air, and is converted into phosphoric acid; has a great tendency to unite with an additional quantity of oxygen, and is, therefore, a powerful deoxidizing agent, and hence, like sulphurous acid, precipitates mercury, silver, platinum and gold, from

their saline combinations in the metallic form; by nitric acid it is converted into phosphoric acid.

PREPARATION. This acid can only be obtained in a state of purity by subliming phosphorus through powdered corrosive sublimate, contained in a glass tube. A liquid comes over which is a compound of chlorine and phosphorus. When this substance is put into water, a peculiar change takes place. A portion of water is decomposed; its hydrogen unites with the chlorine and forms muriatic acid; while the oxygen combines with the phosphorus and forms phosphorus acid. The solution is then evaporated to the consistence of syrup, to expel the muriatic acid; and the residue, which is the hydrate of phosphorous acid, becomes a crystalline solid on cooling.

Phosphoric Acid.—Atom. Num. 35·7—Symb. $2\frac{1}{2}O+P$.

It seems now to be admitted that under the term *phosphoric acid* two distinct acids, the *phosphoric* and *pyrophosphoric* have heretofore been usually included. These compounds are of great interest as affording an example of a fact but recently noticed, viz:—That two bodies may consist of the same ingredients, in the same proportions, and yet differ essentially in their chemical properties. For such compounds, of which several are now known, Berzelius has proposed the general appellation of *isomeric*, from the Greek *isomeres*, expressive of equality, in the ingredients.

The phosphoric and pyrophosphoric acids are thus distinguished from each other. *Phosphoric acid* gives a yellow salt with oxide of silver, but does not affect albumen. *Pyrophosphoric acid* yields a white salt with oxide of silver and precipitates solution of albumen.

These acids as well as the salts which they form are easily converted into each other; and during these changes there is neither gain nor loss of either of their elements. Thus by a red heat the phosphoric acid is converted into the pyrophosphoric; and the pyrophosphoric is reconverted into the phosphoric in the course of a few days by cold water, and rapidly by hot water and the acids:—and the salts are subjected to similar changes by the application of the same agents.

Phosphoric acid.—This acid exists only in solution, for the application of heat necessary to expel the water converts it into the pyrophosphoric. It has an intensely sour taste, reddens litmus, and neutralizes the alkalies, but does not destroy the texture of the skin.

PREPARATION. This acid is readily prepared by boiling an aqueous solution of pyrophosphoric acid.

Pyrophosphoric acid.—Discovered by Mr. Clarke of Glasgow in 1827, [*Brewster's Jour.* vii. 298.] and distinguished from the preceding by the characters above given.

PREPARATION. When phosphorus is burned in a dry vessel of air or oxygen gas, a copious white smoke appears, which soon collects into distinct particles and falls to the bottom of the vessel like flakes of snow. This substance, which is a white, bulky, rather tenacious solid, is an hydrous pyrophosphoric acid. On exposure to the air it rapidly absorbs moisture, with which it constitutes drops of a densely acid solution. When kept for a day or two, it becomes phosphoric acid.

This acid may be also obtained by the cautious addition of phosphor-

us to concentrated nitric acid, evaporating the solution thus obtained and subjecting it to a red heat. But this process requires great care—and a cheaper and easier method consists, in mixing biphosphate of lime obtained from bones as already described, with carbonate of ammonia; boiling the mixture for a few minutes, then filtering, and evaporating the liquid to dryness—and igniting it in a platinum crucible.

It will be observed that in the processes just noticed, phosphoric acid exists in solution, but by the application of red heat it becomes pyro-phosphoric acid, which remains in the crucible united with water. It concretes on cooling into a kind of glass, which has long been known under the name of *Glacial Phosphoric Acid.*

REFERENCES. *The papers of Sir H. Davy already quoted. For abstracts of researches on the combinations of Phosphorus and Oxygen, by Dulong, Berzelius, Davy and Thomson, see Ann. of Phil.* ix. xi. *and* xiii. *Chaptal's Chem.* iii. 78. *Johnston's Report on Chemistry. Also, Turner's Chemistry.*

SALTS OF AMMONIA AND THE ACIDS CONTAINING PHOSPHORUS.

Hypophosphite of Ammonia. Very soluble both in water and in alcohol. Its composition has not been ascertained.

Phosphite of Ammonia.—A very soluble salt, which is with difficulty brought to crystallize.

Phosphate of Ammonia.—Crystallizes in low four-sided pyramids with square bases; soluble in twice its weight of water at 55° F.; when heated it fuses, swells, and if the heat be strongly urged, loses its alkaline base, the phosphoric acid being left in the glacial form.

This salt may be formed by saturating phosphoric acid with ammonia.

Besides the above, which is a neutral salt, there is also a *bi-phosphate.*

PHOSPHORUS AND CHLORINE.

There are two compounds of chlorine and phosphorus, viz. the *Protochloride* and the *Perchloride.*

Protochloride of Phosphorus—Atom. Num. $68·87$—*Symb.* $1\frac{1}{2}Cl+P$—*Sp. gr.* $1·45$ water$=1$.

PROPERTIES. A transparent and colourless liquid; it does not affect the colour of litmus paper, but the fumes, which it gives off in abundance, are acid, owing to contact with the moisture of the atmosphere; acts energetically upon water, the hydrogen combining with the chlorine, forming muriatic acid, and the oxygen with the phosphorus, by which the phosphorous acid is produced, as before described, (p. 167); in which process the muriatic acid is driven off by heat, and pure phosphorous acid remains.

PREPARATION. This compound may be made either by heating the perchloride with phosphorus, or by passing the vapour of phosphorus over corrosive sublimate, heated in a glass tube.

Perchloride of Phosphorus—Atom. Num. 104·23—*Symb.* 2¼Cl+P.

When phosphorus is introduced into chlorine, it inflames spontaneously, and burns with a pale flame. The product is a white solid, which condenses upon the sides of the vessel.

This solid compound, which is the perchloride of phosphorus, is volatile at a temperature below 212° ; but may be fused under pressure, and crystallizes in cooling. It acts with violence upon water, forming with its elements phosphoric and muriatic acids. When transmitted with oxygen gas through a red-hot porcelain tube, chlorine is evolved, and phosphoric acid is formed, showing that at high temperatures, the affinity of oxygen for phosphorus, is stronger than that of chlorine.— *Henry*, i. 401.

REFERENCES. *Davy in Phil. Trans. for* 1812, *under the names of* " *Phosphorane*" *and* " *Phosphorana.*" *Also, his Elements of Chem. Phil. Gay Lussac and Thenard, Recherches, Phys. Chim.* ii.

PHOSPHORUS AND BROMINE.

When bromine and phosphorus are brought into contact in a flask filled with carbonic acid gas, they act suddenly on each other with the evolution of heat and light, and two compounds are generated ; one a crystalline solid which is sublimed and collects in the upper part of the flask, and the other a fluid, which remains at the bottom. The latter is regarded by M. Balard as a *Protobromide*, and the former as a *Deutobromide of Phosphorus.*

PHOSPHORUS AND IODINE.

Iodine and phosphorus combine readily in the cold, evolving so much caloric as to kindle the phosphorus, if the experiment is made in the open air ; but in close vessels no light appears. The combination takes place in several proportions, which have not been determined. Its most interesting property is that of decomposing water, with the formation of hydriodic and phosphoric acids.

REFERENCES. *Davy, in Phil. Trans.* 1814. *Gay Lussac, in Ann. de Chim.* xci. 9.

PHOSPHORUS AND HYDROGEN.

Of all the compounds to which chemists have directed their attention, none are perhaps less perfectly understood than those of phosphorus and hydrogen. All writers on the subject with the exception of Mr. Dalton, who contends that there is only one species of phosphuretted hydrogen, admit the existence of two at least. To these Dr. Thomson has added a third, which does not, however, appear yet to have been examined by other chemists. Berzelius recognizes four compounds of phosphorus and hydrogen, containing different proportions of hydrogen united to the same of phosphorus.--- *Traité de Chim.* i. 263.

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Hydruret of Phosphorus.*

SYN. *Perphosphuretted Hydrogen Gas. Phosphure Trihydrique.*—
Berzelius.

Discovered in the year 1783, by Gengembre, and since particular-
ly examined by Mr. Dalton, Dr. Thomson, M. Dumas and Prof. H.
Rose.

PROPERTIES. A colourless gas, possessing a highly offensive smell,
resembling that of garlic, and a bitter taste; it is very slightly soluble
in water; does not support flame or respiration; inflames spontane-
ously when mixed with air or oxygen gas; its specific gravity is 1·1
according to Dalton, 0·9027 according to Dr. Thomson, and 1·761 ac-
cording to Dumas.

It is slightly absorbed by water.—Recently boiled water, according to
Dalton, absorbs fully one-eighth of its bulk of this gas, most of which
is again expelled by boiling or agitation with other gases; but Dr.
Thomson states that water takes up only about five per cent of its vol-
ume. The aqueous solution does not redden litmus paper, nor does
the gas itself possess any of the properties of acids. The gas is free-
ly and completely absorbed by a solution of sulphate of copper and
chloride of lime, by which means its purity may be ascertained, and
the presence of hydrogen detected.

When this gas is allowed to stand for a few days over water, it de-
posites part of its phosphorus without change of volume, and ceases to
be spontaneously combustible when mixed with atmospheric air. Ac-
cording to Dr. Thomson, it parts with 1-4th of its phosphorus under
these circumstances, and a peculiar gas, which he has called *Subphos-
phuretted Hydrogen,* is generated; but M. Dumas maintains that 1-3d
of the phosphorus is deposited, and that the new gas is identical with
protophosphuretted hydrogen, (bihydruret of phosphorus.)

It inflames spontaneously when admitted into air or oxygen gas.—
This is the most remarkable property of this gas, and by means of
which it is distinguished from all other gases. If the beak of the re-
tort from which it issues, is plunged under water, so that successive
bubbles of the gas may arise through the liquid, a very beautiful ap-
pearance takes place. Each bubble on reaching the surface of the wa-
ter bursts into a flame, and forms a ring of dense white smoke, which
enlarges as it ascends, and retains its shape, if the air is tranquil, until
it disappears. This takes place even at the temperature of freezing
mercury, as observed by Rose. [*Ann. de Chim. et de Ph. Feb. and Aug.*
1827.] If received into a vessel of oxygen gas, the entrance of each
bubble is instantly followed by a strong concussion, and a flash of
white light of extreme intensity. Hence this experiment should be
performed with some caution.—*Silliman's Jour.* vi. 187.

PREPARATION. Hydruret of phosphorus may be prepared in several
ways.

1. By throwing into water the phosphuret of any metal, which me-

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* According to Prof. H. Rose, this gas and the next have the same composi-
tion and specific gravity; both consisting of one volume phosphorus vapour+
three volumes hydrogen, condensed into two volumes. And this view is said
to be confirmed by a fact noticed by Serullas.—*Johnston's Report on Chem-
istry.*

tal *per se* will decompose water, as phosphuret of potassium, sodium, calcium, &c.

2. From a combination of phosphorus and the oxides of these metals, as potash, soda, lime, &c,, by the application of a sufficient heat to enable the phosphorus to effect a decomposition of these oxides.

2. By the addition of a dilute acid to phosphorus and those metals which are usually employed in procuring hydrogen gas, as iron, zinc, &c.—*Silliman's Jour.* xii. 294.

The following is an easy process for procuring a small quantity of this gas. Fill a retort capable of holding about a gill, with a solution of caustic potash. Introduce into the retort a piece of phosphorus an inch and a half or two inches in length, and having closed the beak with the thumb, place it in a small vessel of water. The retort being supported by a stand, apply the heat of a lamp. In a few minutes the gas will be formed, and, forcing out the alkaline solution from the tube of the retort, will at length rise through the water, take fire, and exhibit the wreath so characteristic of this substance. After the gas has ceased to come over, the heat should be very gradually reduced, so as to prevent the sudden rush of water into the retort which would otherwise take place.

Bihydruret of Phosphorus.*

Syn. *Protophosphuretted Hydrogen*, Dumas. *Hydrophosphoric Gas*, Davy. *Phosphure Bihydrique*, Berzelius.
Discovered by Sir H. Davy in 1812.

PROPERTIES. A colourless gas, of a disagreeable odour, though less fetid than the foregoing ; is absorbed by water ; does not take fire spontaneously when mixed with air or oxygen gas at common temperatures, but the mixture detonates with the electric spark, or when heated to 300° F.; admitted into a vessel of chlorine, it inflames instantly and emits a white light, a property which it possesses in common with perphosphuretted hydrogen ; its specific gravity is estimated by Dr. Thomson at 0·9722 ; but M. Dumas found it to be 1·214.

PREPARATION. This gas was prepared by Sir H. Davy by exposing to heat in a retort the solid hydrate of phosphorous acid ; and the same gas is evolved by treating the hydrous hypophosphorous acid in the same manner. It is also formed, according to Dumas, by the action of concentrated muriatic acid on phosphuret of lime ; and likewise by the spontaneous decomposition of perphosphuretted hydrogen gas.

REFERENCES. *Dalton's New Syst. of Chem. Phil. Sir H. Davy in Phil. Trans.* 1812, *containing the first particular examination of Bihydruret of Phosphorus. Thomson's Experiments on Phos. Hyd. Gas, Ann. of Phil.* viii. 87. *The Essays of Dumas and of Rose, Ann. de Ch. et de Phys.* xxxi. xxxiv. *Henry's Chem.* ii. 692.

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* This is now thought to be a compound of 3 hydrogen+1 phosphorus, and to be analogous in its composition to Ammonia. And one of the most curious facts lately made out with regard to it, is that it agrees also with ammonia in its power of forming crystallizable compounds with the hydrogen acids.—These compounds are, moreover, similar in constitution and in crystalline form to the analogous salts of ammonia.—*Johnston's Report on Chemistry.*

PHOSPHORUS AND SULPHUR.

Sulphuret of Phosphorus.

When sulphur is brought into contact with fused phosphorus, they unite readily, but in proportions which have not been precisely determined ; and they frequently react on each other with such violence as to cause an explosion. These substances may also be made to combine by agitation under water, the temperature of which should not exceed 160° F. The compound has a reddish brown colour, and is fluid at about 40° F. It is more fusible than phosphorus, and is highly combustible.—*Brande's Jour.* iv. 361.

REFERENCES. *Pelletier, Ann. de Chim.* iv. 10. *Accum and Briggs, Nicholson's Jour.* vi. *and* vii.

SECTION V.

CARBON.

Atom. Num. 6—Symb. C—Sp. gr. 3·52 water=1.

Perfectly pure carbon is rare in nature, and cannot be prepared by art. It only occurs in a precious stone called the *diamond*.

The diamond is found in many parts of the East Indies, especially in the provinces of Golconda and Visapour, in Bengal, and in the island of Borneo. About the year 1720, diamonds were first found in the district of Serra Dofrio, in Brazil. They always occur in detached crystals in alluvial soil. The primitive form of the diamond is the regular octahedron, each triangular facet of which is sometimes replaced by six secondary triangles, bounded by curved lines ; so that the crystal becomes spheroidal, and presents 48 facets. Diamonds with 12 and 24 facets are not uncommon. [*Jameson's Mineralogy.*] The diamond has been found nearly of all colours ; those which are colourless are most esteemed ; then those of a decided red, blue or green tint. Black diamonds are extremely rare. Those which are slightly brown or tinged with other colours, are least valuable. It is the hardest body in nature. The best tempered steel does not scratch it. It refracts light powerfully, and hence Newton was led to conjecture its combustibility ; a conjecture which was rendered probable by the experiments of the Florentine academicians in 1694, and which was subsequently confirmed by several philosophers. The products of its combustion were first examined by Lavoisier in 1772, and subsequently with more precision by Guyton Morveau, in 1785. [*Ann. de Chim.* xxxi.] In 1797, Mr. Tennant demonstrated the important fact, that when equal weights of diamond and pure charcoal were submitted to the action of red hot nitre, the results were in both cases the same ; and in 1807, the combustion of the diamond in pure oxygen, was found by Messrs. Allen and Pepys to be attended with precisely the same results as the combustion of pure charcoal. Hence the inevitable inference that charcoal and the diamond are substances similar in their chemical nature ; differing only in their mechanical texture. [*Phil. Trans.* 1807.] This view was confirmed by Sir H. Davy, [*Phil. Trans.* 1814,] who compared the product of the combustion of the diamond with that derived from different kinds of charcoal. Further proof of the identity of charcoal and

the diamond, is furnished by the fact that the diamond converts iron into steel, under circumstances quite free from all sources of fallacy. —*Phil. Trans.* 1815, 371.

Next to the diamond the most remarkable and purest forms of carbon, are

1. *Graphite* or *Black Lead.*—A mineral of a lead gray colour, from which common crayons are manufactured, found in beds in mountains belonging to primitive formations. As it generally leaves after its combustion a cinder which contains much iron, it was supposed to be a compound of carbon with about 5 per cent. of this metal. But more recent researches, especially those of Karsten, have proved beyond a doubt that it is a peculiar form of carbon, and that the foreign substances which accompany it, are merely accidental. The graphite of Barreros in Brazil, leaves scarcely a trace of residuum when it is burned.—*Berzelius,* i. 313.

2. *Anthracite.*—Another species of fossil carbon, differing from coal in that, when sufficiently heated, it burns without flame, odour or smoke.

3. *Coke.*—A name applied in England to a carbonaceous mass of an iron black colour, and semi-metallic lustre, which remains after coal has been deprived, by means of heat, of all the volatile parts which it contains.

4. *Charcoal.*—A substance obtained by burying in sand, in a crucible, pieces of oak, willow, hazel, or other woods deprived of bark, and exposing them covered to the strongest heat of a wind furnace. For purposes of accuracy, charcoal must be used when recently prepared, and before it has had time to become cold; or if it cannot be had fresh made, it must be heated again to redness under sand in a crucible.

Different kinds of wood furnish variable quantities of charcoal; mahogany, oak, fir and box are the most highly esteemed.—*See Allen and Pepy's, Phil. Trans.* 1807.

In the large way, charcoal is often prepared by the distillation of wood in cast-iron cylinders. The loppings of young trees, commonly called crop-wood, are generally employed; and besides the charcoal, liquid products of value are collected, especially an impure vinegar, known under the name of pyroligneous acid.—*Parkes' Chem. Essays,* ii. 271.

The more common method, in this country especially, is to form the wood into a conical pile, which being covered with earth or clay, is suffered to burn with a limited access of atmospheric air, by which its complete combustion, or reduction to ashes, is prevented.

5. *Lampblack.*—This is obtained chiefly by turpentine manufacturers, from refuse resin, which is burned in a furnace so constructed that the dense smoke arising from it may pass into chambers hung with sacking, where the soot is deposited, and is swept off from time to time, and sold without further preparation. When heated red hot in a close vessel, it forms a very pure carbon. Lampblack may also be obtained by passing the vapour of the oil of turpentine, or of spirit of wine, through a red hot tube; or by the combustion of camphor, which forms the basis of a very fine black paint.

6. *Animal Charcoal.*—This is obtained by subjecting bones to a red heat in a covered crucible. It is a black mass, of a metallic lustre,

consisting of charcoal mixed with the earthy matters of the bone.—
When reduced to powder, it occurs in commerce under the name of
Ivory black.

7. A new and curious form of carbon has been described by Dr.
Colquhoun of Glasgow. When coal gas is passed over red hot iron,
in Mr. Mackintosh's process for converting iron into steel, this variety
of carbon is deposited in long capillary threads, very fine, brittle, per-
fectly black, and having considerable lustre. In its external appear-
ance, though this is the most perfect, many shades of difference occur.
—*Ann. of Phil.* xxviii. 1.

PROPERTIES OF CHARCOAL. A black, insoluble, inodorous, insipid,
brittle substance; an excellent conductor of electricity, but a bad con-
ductor of heat;[*] unchanged by the combined action of air and moist-
ure at common temperatures; infusible, and easily combustible in oxy-
gen gas; is capable of destroying the smell and taste of a variety of
vegetable and animal substances.—*Lowitz, Crell's Annals,* ii. 165.

Charcoal has the property of absorbing gases without alteration.—Fill
a jar with common air, or any other gas, and place it over dry mercu-
ry; take a piece of charcoal, red-hot from the fire, and plunge it in
the mercury of the bath; when cold, let it be passed into the vessel of
gas, without bringing it into contact with the atmosphere. A consi-
derable diminution of the gas will be effected; and in 24 or 36 hours
its absorption will be completed.

This property of charcoal has been made the subject of valuable sets
of experiments by Saussure and Count Morozzo. [*Ann. of Phil.*
vi. 241. *Henry's Chem.* i. 361.] The absorption appears to be a mere
mechanical effect; for even those gases which have an affinity for
charcoal, (as hydrogen and oxygen,) are given out unchanged at the
heat of boiling water.— *Thenard.*

It resists the putrefaction of animal substances.—Meat which has be-
come tainted may even have its sweetness restored by rubbing it with
charcoal, and may be preserved sweet by being buried in its powder.
It also produces the remarkable effect of destroying the colour and
smell of many animal and vegetable substances. Common vinegar,
by being boiled with it, becomes perfectly colourless; and red wines,
rum or brandy may be bleached by filtration through it. It is largely
employed, for this purpose, in the process of sugar refining, and for
preparing colourless crystals of citric acid and other vegetable pro-
ductions. Charcoal, prepared by calcining animal substances in close
vessels, has been found most efficacious for these purposes.—*Ann. de
Chim.* lxxix. 80. *Brande's Jour.* iv. 367. *See also Graham's paper on
the effects of Animal Charcoal on solutions, Brande's Jour. N. S.* vii.
120.

It is a very slow conductor of heat.—The experiments of Guyton
Morveau have determined, that caloric is conveyed through charcoal

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[*] Dr. Thomson states, on the authority of Cheuvreusse, that charcoal formed
under a red heat is a non-conductor of electricity, and cannot be employed as
one of the elements of the Voltaic battery. It is also a bad conductor of
heat. Charcoal formed by a red heat is an excellent conductor of electricity
and of heat, and is not nearly so combustible as the first species.—*Inorganic
Chem.* i. 149.

more slowly than through sand, in the proportion of three to two. Hence powdered charcoal may be advantageously employed to surround substances which are to be kept cool in a warm atmosphere; and also to confine the caloric of heated bodies. It affords, however, an easy transmission to the electric fluid.

Spontaneous inflammation of powdered charcoal.—It has long been known that charcoal in a state of fine powder, often inflames spontaneously. The subject has recently been examined by Col. Aubert of the French artillery, and others, and some interesting facts have been made known. It appears that spontaneous combustion ensues in almost all cases when 20 or 30 cwt. of charcoal in a state of minute division, are put together in a heap and left undisturbed. Col. Aubert ascribes the combustion in such cases to the absorption of air, which occasions a disengagement of heat; but it is most probably owing, as is suggested by Mr. Davies, to the action of air and moisture on the minute portions of potassium which charcoal contains. Perhaps this may also account, at least in some degree, for the singular power of absorption which charcoal possesses.—*See Lond. and Edin. Phil. Mag.* iii. 1 and 89.

REFERENCES. *Tennant on the nature of the Diamond, Phil. Trans.* 1797. *Repert. of Arts,* 1st ser. viii. 118. *Mawe's Treatise on Diamonds, &c. Cheurreusse's Physico-Chemical Researches on Charcoal, Ann. de Chim. Aug.* 1825, *and in Repert. of Patent Inventions,* ii. 387. *Parkes' Chem. Essays, contain an account of the various forms of Carbon, methods of preparing Charcoal, &c. Dumas, Chimie appliquée aux Arts.*

CARBON AND OXYGEN.

There are two compounds of these substances, the one known under the name of *Carbonic Oxide*, the other of *Carbonic Acid.*

Carbonic Oxide.—Atom. Num. 14—*Symb.* $O+C$—*Sp. gr.* 0·9721 air=1.

SYN. *Gaseous Oxide of Carbon.*
This gas appears to have been first obtained by Dr. Priestley; but its true nature was first made known by Mr. Cruickshank of Woolwich, in 1802.—[*Nicholson's Jour.* 4to. v.] and it was afterwards more particularly examined by M. M. Clement and Desormes.—*Ann. de Chim.* xxxix. 26.

PROPERTIES. A gaseous body, of an offensive smell, colourless and insipid; very sparingly soluble in water, and it does not in any way affect the colour of blue vegetable infusions; it is inflammable, and when set on fire as it issues from the orifice of a small pipe, burns with a feeble blue flame, but a lighted taper plunged into a jar full of the gas is instantly extinguished; is noxious to animal life, when received into the lungs, and when respired for a few minutes produces giddiness and fainting.—*Phil. Mag.* xliii. 367. *Beck's Med. Juris.*
When a mixture of carbonic oxide and an equal bulk of hydrogen, is passed through an ignited tube, the tube becomes lined with charcoal. At this temperature, the hydrogen attracts oxygen more strongly than it is retained by the charcoal, and water is formed. When mixed with half its volume of oxygen gas, and the mixture fired over mercury, in a detonating tube, 150 measures of the mixture will be

converted into 100 measures of carbonic acid, if the gases employed be perfectly pure. It was found, also, by Gay Lussac, that carbonic oxide is decomposed by the action of potassium, which combines with the oxygen, and precipitates charcoal; and Dobereiner, by bringing it into contact with sulphuretted oxide of platinum, converted it into half its volume of carbonic acid.

PREPARATION. This gas may be prepared in either of the following ways.

1. By introducing into a gun barrel a mixture of equal parts of well dried carbonate of baryta, or of lime, (common chalk,) and charcoal pulverized, or of chalk and dry zinc or iron filings, and exposing them to a strong heat. In this case the charcoal, iron of zinc filings, combine with one proportion of oxygen in the carbonic acid or the carbonate of lime or baryta, and convert it into carbonic oxide.

2. By transmitting carbonic acid gas over charcoal ignited in a porcelain tube, the acid gas combines with an additional dose of charcoal, loses its acid properties, and is converted into a double volume of carbonic oxide.

3. By mixing binoxalate of potassa, [salt of sorrel,] with five or six times its weight of concentrated sulphuric acid, and heating the mixture in a glass bottle. [*Dumas, Ann. de Chim. et de Phys.* xxxiii. 110.] The evolved gas, after removing the carbonic acid by washing in lime water or liquid potassa, is pure carbonic oxide. This washing is, indeed, necessary, from whatever source this gas may have been obtained.

To understand the theory of this process, we should remark that oxalic acid is a compound of equal measures of carbonic acid and carbonic oxide, or at least its elements are in the proportion to form these gases; and that it cannot exist unless in combination with water, or some other substance. N w the sulphuric acid unites with both the potassa and water of the binoxalate, and the oxalic acid being thus set free, is instantly decomposed. Oxalic acid may be substituted in this process for the binoxalate of potassa.

Carbonic Acid.— Atom. Num. 22*—Symb.* $2O+C$*—Sp. gr.* $1\cdot5277$
air $=1$.

This acid was discovered by Dr. Black, in 1757, and described by him, in his inaugural dissertation, *de Magnesia Alba*, under the name of *Fixed Air*. Its nature was first demonstrated synthetically by Lavoisier, and analytically by Mr. Tenant.

PROPERTIES. A colourless, inodorous, elastic fluid, possessing all the physical properties of the gases in a high degree, and requiring a pressure of thirty-six atmospheres to condense it into a liquid; it is rather more than by one half heavier than atmospheric air; it is perfectly uninflammable, and instantly extinguishes flame; is speedily fatal to animal life, even when in moderate proportion; is absorbed by water to the amount of its own bulk, under common pressure and temperature, but the quantity taken up may be greatly increased by increasing the pressure; the solution has an agreeable subacid taste, and reddens paper stained with the blue colour of litmus.

It extinguishes flame.—Set a vessel filled with the gas, with its mouth upwards, and let down a lighted candle. The candle will be instantly

extinguished. The combustion, in this case, does not cease from the want of oxygen only, as appears from the fact that a candle cannot burn in a gaseous mixture composed of four measures of atmospheric air and one of carbonic acid. It appears therefore to exert a positive influence in checking combustion.

It is heavier than atmospheric air.—From the great specific gravity of carbonic acid, it will remain for some time at the bottom of a jar with its mouth turned upwards ; and may be poured from one such vessel into another like water. It is an amusing experiment to place a lighted taper in the bottom of the jar, as it will be instantly extinguished by pouring the gas upon it like a liquid.

It is owing to the same property that carbonic acid gas is often found at the bottom of grottoes, of deep wells and of mines, the upper part of which is entirely free from it, and which, from its injurious effects, is called by the miners, *choak damp.* Hence the precautions, used by the sinkers of wells, of letting down a candle before they venture to descend in person.*

It is absorbed by water.—This may be easily demonstrated, by agitating the gas with that liquid, or by leaving a jar full of it inverted over water. In the first case the gas disappears in the course of a minute ; in the latter it is absorbed gradually. If more pressure be applied, the amount absorbed by water is greatly increased. Dr. Henry has ascertained, from an extensive series of experiments, that the quantity of gas absorbed by water is directly as the pressure ; that is, water dissolves twice its volume, when the pressure is double, and three times its volume, when the pressure is treble, &c. [*Henry's Chem.* i. 472. *Phil. Trans.* 1803.] It is by the strong compression of a forcing pump that the common soda water is so highly charged with this gas.

The pleasant pungency of brisk and sparkling fermented liquors is owing to the carbonic acid which they hold in solution, and which they lose upon exposure to the air, and thereby become flat and stale.

It possesses acid properties.—This may be shown by dipping into water impregnated with it, a bit of litmus paper, or by mixing with a portion of the liquid about an equal bulk of infusion of litmus ; in both cases the litmus will be reddened. This fact establishes the title of the gas to be ranked among acids. When an infusion of litmus, which has been thus reddened, is either heated or exposed to the air, its blue colour is restored, in consequence of the escape of carbonic acid. This is a marked ground of distinction from most other acids, the effect of which is permanent, even after boiling.

It produces turbidness and precipitation when passed through lime water.—This is produced by the combination of the lime with the gas, forming carbonate of lime, which, from its insolubility in water, at first renders the solution milky, and afterwards forms a white flaky precipitate. Hence lime water is not only a valuable test of the presence

* This can generally be depended on ; but Dr. Christison states that some instances have been known of the atmosphere being sufficiently loaded with carbonic acid to produce insensibility, and yet not so impure as to extinguish a burning candle.—*Treatise on Poisons.*

of carbonic acid, but is frequently used to withdraw it altogether from any gaseous mixture that contains it ; but in order to effect its entire absorption, recourse must be had to a solution of caustic potassa or soda.

Solidification of Carbonic acid.—It has been recently ascertained that by subjecting gaseous carbonic acid to great pressure, it is converted into a solid, resembling compact snow, which during its liquefaction produces an intense degree of cold. M. Thilorier, who has invented an apparatus of very simple construction for obtaining the solid acid, states that when the bulb of a thermometer was placed in the midst of a small portion of solid carbonic acid, in two minutes the index became stationary, having sunk to $-162°$ F. Alcohol uniting with the solid acid, congeals, forming a hard, brilliant and semi-transparent ice ; but the congelation of anhydrous alcohol does not occur unless it is mixed with the acid, for when the alcohol is poured into a silver tube, and this plunged into solid carbonic acid, no change is produced.

Although the addition of ether or alcohol does not increase the degree of cold, yet it enables the solid acid to moisten, and to adhere more closely to the surfaces of bodies, thus greatly increasing its refrigerating power. A portion of carbonic acid, on the addition of a few drops of alcohol or ether, will solidify from fifteen to twenty times its weight of mercury, thus affording an easy and elegant method, far superior to any yet used, for the solidification of this metal.—*Lond. and Edin. Phil. Mag. &c.* x. 158.

SOURCES AND PREPARATION. Carbonic acid is produced in several cases of combustion ; and also during the process of respiration. It is moreover a constant ingredient of atmospheric air. (See page 132.)

It may be artificially prepared by burning carbon, either pure charcoal or the diamond, in oxygen gas. But it is most conveniently obtained, for the purposes of experiment, by the action of muriatic acid, diluted with two or three times its weight of water, on fragments of marble. The muriatic acid unites with the lime, forming a muriate of lime, and carbonic acid gas escapes, with effervescence. It may also be obtained by subjecting any of the carbonates, and especially carbonate of lime, to heat in an iron retort.

ACTION ON THE ANIMAL ECONOMY. When an attempt is made to inspire pure carbonic acid, a violent spasm of the glottis takes place, which prevents the gas from entering the lungs. If it be so much diluted with air as to admit of its passing the glottis, it then acts as a narcotic poison on the system. It is this gas which has often proved destructive to persons sleeping in a confined room with a pan of burning charcoal.

REFERENCES. *Chaptal's Chem.* iii. 12, *containing a detailed account of Carbonic Acid. Saussure on the quantity of, in the Atmosphere, Ann. de Ch. et de Ph.* ii. 199, *and Ann. of Phil.* ix. 41. *On the quantity of Carbonic Acid emitted from the lungs during respiration, at different times, see the very able papers of Prout, in the Ann. of Phil.* ii. 328. *and* iv. 331. *Faraday, on the liquefaction of Carbonic Acid. Ann. of Phil.* xxiii. 95. *Brunel's Apparatus for the condensation of, into a liquid, Repert. of Pat. Invent.* ii. 157.

SALTS OF CARBONIC ACID AND AMMONIA.

Carbonate of Ammonia.—*Atom. Num.* 39 —*Symb.* (2H+N)+(2O +C.)

A dry white volatile powder, which has an ammoniacal odour and alkaline properties ;—obtained only by mixing dry carbonic acid over mercury with twice its volume of ammoniacal gas.

Sesquicarbonate of Ammonia.—*Atom. Num.* 59—*Symb.* (3H+N)+1½ (2O+C)+1aq.

SYN. *Subcarbonate of Ammonia*—U. S. Phar.

PROPERTIES. When fresh prepared, this salt has a crystalline appearance, and some transparency, and is hard and compact ; it has a pungent smell, and a sharp penetrating taste, and affects vegetable blues as uncombined alkalies do ; it dissolves in twice its weight of cold, or an equal weight of boiling water, but at the latter temperature it gives off part of its acid ; when exposed to the atmosphere it loses weight very fast, ceases to be transparent, and becomes inodorous, brittle, and easily reducible to powder, which is the bicarbonate.

PREPARATION. The sesquicarbonate of ammonia is prepared by heating a mixture of one part of muriate of ammonia with one part and a half of carbonate of lime, carefully dried. Double decomposition ensues during the process ; muriate of lime remains in the retort, and the sesquicarbonate of ammonia is sublimed. The carbonic acid and ammonia are, indeed, in proper proportion in the mixture for forming the real carbonate ; but from the heat employed in the sublimation, part of the ammonia is disengaged in a free state.

Bicarbonate of Ammonia.—*Atom. Num.* 61—*Symb.* (3H+N)+2(2O +C).

Crystallizes in small six-sided prisms, which have no smell, and but little taste. It was formed by Berthollet by transmitting a current of carbonic acid gas through a solution of the common carbonate of ammonia of the shops. On evaporating the liquid, the bicarbonate is deposited in a crystalline form.

REFERENCES. *Ure's Experimental Researches on the Ammoniacal Salts, Ann. of Phil.* x. 203, 278. *R. Phillips on the Carbonate of Ammonia, &c. Brande's Jour.* vii. 294. *Same author on the Bicarbonate of Ammonia, Ann. of Phil.* xvii. 110.

CARBON AND CHLORINE.

For our knowledge of two compounds of these bodies, we are indebted to the able researches of Mr. Faraday. [*Phil. Trans.* 1821.] Another was first described by M. Julin of Abo. [*Ann. of Phil.* xvii. 216.] And recently a fourth has been added by Liebig. The composition of these chlorides will be seen by the following table :

Subchloride of Carbon,	$Cl+2C= 47.45$
Protochloride of Carbon,	$Cl+ C= 41.45$
New Chloride of Liebig,	$2\frac{1}{2}Cl+2C=100.63$
Perchloride of Carbon,	$3Cl+2C=118.35$

Subchloride of Carbon.—This compound was discovered, in small quantities, by M. Julin, in a manufactory of nitric acid, from nitre and sulphate of iron, in Sweden. It is in the form of white feathery crystals, rather heavier than water, and insoluble in that fluid. It has a peculiar smell, resembling spermaceti, and is tasteless. It is soluble in alcohol and ether, and burns in the flame of a lamp, with a greenish colour. It was made the subject of analysis by Messrs. R. Phillips and Faraday.

Protochloride of Carbon.—A limpid and colourless fluid; does not assume the solid form even at 0° F.; is volatilized at 160° or 170° F.; may be distilled without change, but is partly decomposed at a red heat; sp. gr. 1·5526.

This compound is obtained by passing the vapour of perchloride of carbon through an ignited glass tube containing fragments of glass or rock crystal, to increase the heated surface. The perchloride is partly decomposed, chlorine escapes and a fluid passes over which may be separately condensed and is the protochloride.

Perchloride of Carbon.—A transparent, colourless, brittle solid, having an aromatic odour resembling that of camphor; sp. gr. 2, being exactly double that of water; fuses at 320° F., boils at 360°, and may be distilled without change, assuming a crystalline form as it condenses; burns vividly in oxygen gas, and with a red light when held in the flame of a spirit lamp; is soluble in alcohol, ether, and in the fixed and volatile oils, but sparingly so in water.

This chloride is obtained by mixing olefiant gas (a compound of chlorine and hydrogen,) with chlorine, and exposing the oily liquid which results from their combination to the direct solar rays, in a vessel full of chlorine gas. The chlorine acts upon and decomposes the liquid, muriatic acid is liberated, and the carbon, at the moment of separation, unites with chlorine.

REFERENCES. *Faraday's Memoir, containing a detailed account of the two last compounds, republished from the Phil. Trans. in the Ann. of Phil.* xviii. 104.

New Chloride of Liebig.—A limpid, colourless liquid, similar in odour and appearance to the oily fluid which chlorine forms with olefiant gas; density 1·48; boils at 141° F.; is soluble in alcohol and ether, but not in water; is feebly combustible, and is not changed at moderate temperatures either by acids or alkalies.

The new chloride may be conveniently prepared by distilling from a capacious retort, a mixture of 1 pound of chloride of lime, 3 pounds of water, and 2 or 3 ounces either of alcohol or pyro-acetic spirit.

CARBONIC OXIDE AND CHLORINE.

Chlorocarbonic Acid.—Atom. *Num.* 49·45—*Symb.* $(O+C)+Cl.$ *Sp. gr.* 3·4421 air=1.

This compound was discovered in 1812 by Dr. John Davy, who described it in the Philosophical Transactions for that year, under the name of *Phosgene Gas.* It is made by exposing a mixture of equal measures of dry chlorine and carbonic oxide gases to sunshine, when rapid but silent combination ensues, and they contract to one-half

their volume. Diffused daylight also effects their union slowly; but they do not combine at all when the mixture is wholly excluded from light.

PROPERTIES. A colourless gas, having a strong odour, and reddening dry litmus paper. It combines with four times its volume of ammoniacal gas, forming a white solid salt; so that it possesses the characteristic property of acids. By contact with water it is changed into muriatic and carbonic acid gases. Several of the metals decompose it, and unite with the chlorine, evolving carbonic oxide, equivalent in volume to the original gas.

Chlorocarbonic acid then affords an example of an acid with a simple base, and two acidifying principles, oxygen and chlorine, which are not often united in the performance of this function.

Chloral.—This name, derived from the first syllable of the words *chlor*ine and *al*cohol, has been applied by Liebig to a new compound of chlorine, carbon and oxygen, prepared by the mutual action of alcohol and chlorine. It is a colourless, transparent liquid of a penetrating pungent odour, and nearly tasteless, or at most oily ; it boils at 201° F. and may be distilled without change. Liebig considers it to consist of 9 atoms of carbon, 6 chlorine, and 4 oxygen. For details concerning the properties and mode of preparation of this substance, see *Ann. de Chim. et de Phys.* xlix. 146 ; *also Turner's Chem. 5th Lond. Ed.*

CARBON AND BROMINE.

Bromide of Carbon.—This compound is formed by mixing together one part of iodide of carbon and two parts of bromine. Bromides of carbon and of iodine are formed, the latter of which is removed by a solution of caustic potash. It is a colourless liquid, at common temperatures, but crystallizes at 32° F. It has a sweetish taste, an ethereal odour, is very volatile, and scarcely soluble in water.—*Berzelius,* i. 360. *Ann. de Chim. et de Phys.* xxxix. 225.

CARBON AND IODINE.

Periodide of Carbon.—When a solution of pure potassa in alcohol is mixed with an alcoholic solution of iodine, a portion of alcohol is decomposed ; and its hydrogen and carbon, uniting separately with iodine, give rise to periodide of carbon and hydriodic acid. ·The latter combines with the potash and remains in solution. The former has a yellow colour, like sulphur, and forms scaly crystals of a pearly lustre ; its taste is very sweet, and it has a strong aromatic odour resembling saffron.—*Ann. de Chim. et de Phys.* xxxvii. 86.

CARBON AND HYDROGEN.

Chemists have for several years been acquainted with two distinct compounds of carbon and hydrogen, the carburetted hydrogen, and the olefiant gas. Besides these, a third has been pointed out by Mr. Dalton, as entering into the composition of oil and coal gas, to which he proposes that, provisionally, the name of *Super-Olefiant Gas* should be given ; and Mr. Faraday has further enlarged our knowledge of these compounds, by making us acquainted with at least two others.

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[*Phil. Trans.* 1825.] According to Dr. Thomson, naphtha and naphthaline, are likewise pure hydrurets of carbon.

The following is a table of the gaseous compounds of carbon and hydrogen:

1. Hydruret of carbon, (Olefiant gas,)   12 C.$+$2 H.$=$14.
2. Bihydruret of carbon,   6 C.$+$2 H.$=$8.
3. Super-olefiant,   18 C.$+$3 H.$=$21.
4. Bicarb.ᵗʰyd.   36 C.$+$3 H.$=$39.
5. Quadrocarb. hyd.   24 C.$+$4 H.$=$28.

It should be remarked, however, that Thenard does not consider the compounds described by Faraday, as distinct; and Berzelius, by not noticing them in his treatise in connection with the other compounds, seems to incline to the same opinion. At all events, their nature is by no means clearly established, and I shall therefore only present a brief notice of them, and refer to authorities, as a guide to those who wish to examine the subject more at length.

Hydruret of Carbon.—Atom. Num. 14—*Symb.* 2 H$+$2 C. *Sp. gr.* 0·9709 air$=$1.

SYN. *Olefiant Gas. Bicarburetted or Percarburetted Hydrogen.*
This gas was discovered in 1796, by some associated Dutch chemists, who gave it the name of *Olefiant Gas.* But the above name appears to be more in conformity with the principles of chemical nomenclature.

PROPERTIES. A colourless elastic fluid, which has no taste, and scarcely any odour when pure; is absorbed by water to the amount of about one-eighth of the volume of the latter; it extinguishes flame, is unable to support the respiration of animals, and when set on fire, as it issues from the orifice of a small pipe, burns slowly, with the emission of a dense white light; when mingled with a proper quantity of oxygen gas, it forms a mixture which may be kindled by flame or the electric spark, and which explodes with great violence; it is decomposed by being passed through red hot tubes of porcelain, and it then deposits its carbon, and is expanded into twice its original volume of hydrogen; it is powerfully acted on by chlorine, uniting with it, as well as with iodine, at ordinary temperatures.

When olefiant gas is mixed with oxygen and fired, it explodes.—If the mixed gases are fired by electricity in a Volta's eudiometer, it is apt, unless very small quantities be employed, to burst the instrument.—One volume requires three volumes of pure oxygen gas, and affords two volumes of carbonic acid gas. But in order to insure the perfect combustion of the inflammable gas, it should be mixed with five times its bulk of oxygen of at least 90 per cent. purity. If too little oxygen be used, charcoal is apt to be precipitated unburned; and a small excess of oxygen does no harm, but remains in the mixture. When fired with less than its own bulk of oxygen, the separation of charcoal is evident, and the bulk of the residue is greater than that of the original gases.—*Henry's Chem.* i. 444.

It may be decomposed by heat.—When it is passed through a porcelain tube at a low red heat, charcoal is deposited, and an equal volume of the bihydruret of carbon is produced; but at a white heat, the latter is also decomposed, and the gas is greatly increased in volume.

It is powerfully acted on by chlorine.—When olefiant gas and chlorine are mixed together in the proportion of one measure of the former and two of the latter, they form a mixture which takes fire on the approach of flame, and which burns rapidly with the formation of muriatic acid gas, and deposition of a large quantity of charcoal. But if the gases are allowed to remain at rest after being mixed together, a very different action ensues. The chlorine, instead of decomposing the olefiant gas, enters into direct combination with it, and a yellow liquid-like oil is generated. This substance is sometimes called *Chloric Ether;* but the term *Chloride of Hydrocarbon,* as indicative of its composition, is more appropriate. Iodine and bromine also form similar compounds with olefiant gas, all of which we shall notice hereafter.

PREPARATION. This gas may be obtained by mixing in a large glass retort, three measures of strong sulphuric acid, and one measure of alcohol, or spirits of wine, and applying heat; the mixture soon assumes a black colour and thick consistence, and a copious disengagement of gaseous matter takes place, which may be collected over water or mercury. After agitation with lime-water or solution of potassa, to separate carbonic and sulphurous acids, pure hydruret of carbon remains.

In order to understand the theory of this process, it is necessary to state, that alcohol is supposed to consist of one proportion of olefiant gas and one of water. The separation of the water is effected by the sulphuric acid, for which it is known to possess a great attraction.— The first portions which escape from the mixture, consist of ether, which will be understood from the fact, that ether consists of two proportions of olefiant gas, combined with one of water, differing therefore from alcohol in the amount of water which it contains, being in this respect intermediate between alcohol and olefiant gas.

Bihydruret of Carbon.—Atom. Num. 8—Symb. 2 H+C—Sp. gr. 0·5554
air=1.

SYN. *Heavy inflammable air.—Gas of marshes.—Hydrocarburet.— Protocarburet of Hydrogen.—Light Carburetted Hydrogen.*
The real nature of this gas was first ascertained by Dalton, and it has since been examined by Sir H. Davy, Thomson, and Henry.

PROPERTIES. A colourless, permanent, gas, soluble in very minute proportions in water, with little odour; it extinguishes all burning bodies, and is of course unable to support the respiration of animals; it is highly inflammable, and when a jet of it is set on fire, it burns with a yellowish flame, and much stronger light than is given out by hydrogen gas; when mixed with atmospheric air or oxygen, in certain proportions, it explodes with violence upon contact with flame; it is in part only resolved into its elements by the most intense heat.

When mixed with oxygen gas and fired, it explodes. To decompose this gas completely, it is necessary to mix it with rather more than twice its bulk of oxygen gas; but exactly two volumes are consumed. Water and a quantity of carbonic acid are produced, the latter being precisely equal to the original bulk of the inflammable gas.

Action of Chlorine.—When bihydruret of carbon and chlorine are mixed together over water, no action takes place if light be carefully excluded; but if exposed to the light of day, and still more rapidly in

the light of the sun, a series of decompositions ensue. Muriatic and carbonic acids are formed, the former of which is instantly absorbed.

PREPARATION AND NATIVE STATE. This compound of carbon and hydrogen may be obtained, mixed, however, with about 1-20 of carbonic acid, and 1-15 or 1-20 of nitrogen gas, by stirring the bottom of almost any stagnant pool of water, especially if formed of clay.—When this is done by an assistant, the gas is copiously disengaged in bubbles, which may be collected either in an inverted glass jar, or in an inverted bottle filled with water, into the mouth of which a funnel is fixed. It should be washed, when collected, with lime-water or liquid potassa.

Bicarburet of Hydrogen.—Atom. Num. 39—Symb. 3H+6C.

When oil gas is subjected, in proper vessels, to a pressure of thirty atmospheres, a fluid is deposited in the proportion of nearly a gallon from 1000 cubic feet, which may be drawn off and preserved in glass bottles of ordinary strength. By repeated distillations, and by exposing the distilled liquid to a temperature of zero, Mr. Faraday obtained a substance to which he has applied the above name.

The bicarburet of hydrogen, at common temperatures, is a colourless transparent liquid, which smells like oil gas, and has also a slight odour of almonds; its specific gravity is nearly 0·85 at 60° F.; at 32° it is congealed, and forms dendritic crystals on the sides of the glass; at zero is transparent, brittle, and pulverulent, and is nearly as hard as loaf-sugar; when exposed to the air, at the ordinary temperature, it evaporates, and boils at 186°; it is only slightly soluble in water, but freely so in alcohol and ether, fixed and volatile oils; it is combustible, and forms a powerful detonating mixture with oxygen.

Quadrocarburet of Hydrogen, or Etherine.—Atom. Num. 28—Symb. 4H+4C.

The second carburet of hydrogen discovered by Mr. Faraday, to which the above names have been applied, was derived from the same source as the preceding. It is obtained by heating with the hand the condensed liquid from oil gas, and conducting the vapour which escapes through tubes cooled artificially to zero. A liquid is thus procured, which boils by slight elevation of temperature, and before the thermometer rises to 32° F., is wholly reconverted into vapour.

This vapour at 60° F. is highly combustible, and burns with a brilliant flame; has the specific gravity of 27 or 28, hydrogen being 1; it is sparingly absorbed by water, but alcohol takes it up in large quantities, and the solution effervesces on being diluted with water; olive oil dissolves about six times its volume, and one volume of sulphuric acid condenses above 100 volumes of the vapour with the evolution of great heat; the acid is much blackened, and on dilution becomes turbid, but gives out no gas.

The vapour on being cooled down to 0° F. is again condensed into a liquid, which when examined in a tube hermetically sealed, has a specific gravity of 0·627 at 54°; it is therefore the lightest liquid body at present known.—*Henry*, i. 450.

REFERENCES. *Faraday in Phil. Trans. for* 1825, *or Ann. of Phil.* xxvii. 44.

*Compounds of Carbon and Hydrogen obtained by the distillation of ani-
mal and vegetable matter, coal tar, &c.*

Paraffine.—A fatty substance without taste or odour, having a density
of 0 87.; inflammable like the fats, burning with a pure white flame,
yielding carbonic acid and water; not acted upon by the acids or al-
kalies; soluble in spirits of turpentine and naphtha even in the cold,
and in the fat oils by aid of heat. It is obtained by distillation from the
petroleum of Rangoon, and from the tar derived from the igneous de-
composition of beach wood and other vegetable matter. It was disco-
vered about the same time by Dr. Reichenbach in Moravia, and by
Dr. Christison of Edinburgh.—*Ann. de Chim. et de Phys.* 1. 69.

Eupione.—A liquid as limpid as alcohol, without taste, colour or
odour; insoluble in water, but soluble in ether, spirits of turpentine,
naphtha, almond oil, bisulphuret of carbon and alcohol, the latter being
the best solvent; it burns with a lively flame, without smoke, yielding
carbonic acid and water.

This substance which is supposed to differ from the preceding only
in containing a smaller proportion of carbon, was discovered by Dr.
Reichenbach, and is best prepared by distillation from the tar derived
from bones or horn, and is purified by distillation from strong sulphur-
ic acid. The adhering acid is removed by washing in an alkaline so-
lution, and the separation of paraffine is effected by means of alcohol
and by cautious distillation along with water.—*Ann. de Chim. et de
Phys.* 1. 60.

Naphtha from Coal Tar.—Coal tar by distillation yields a substance
closely resembling mineral naphtha. It has a strong and empyreuma-
tic odour, and is highly inflammable, burning with a white flame mix-
ed with much smoke; it is insoluble in water, but unites in every pro-
portion with pure alcohol, sulphuric ether, petroleum and the oils.
Potassium may be preserved in it without losing its lustre.

Naphthaline.—Obtained, like the preceding, by distillation from coal
tar. It is a white crystalline solid, heavier than water; has a pungent
aromatic taste, and a peculiar faintly aromatic odour; it fuses at 180°
F. and assumes a crystalline texture in cooling; it voltalizes slowly at
common temperatures, and boils at 410° F.; is not very readily in-
flamed, but when set on fire burns rapidly, and emits a large quantity
of smoke; insoluble in cold, and sparingly soluble in hot water, but
freely so in alcohol and ether; is not acted on by the alkalies, but is
dissolved by the acetic and oxalic acids, forming a pink coloured solu-
tion.

Naphthaline combines with sulphuric acid, and forms an acid which
was first described by Mr. Faraday in 1826, under the name of *Sul-
phonaphthalic Acid.* It has a bitter acid taste, reddens litmus power-
fully, and combines with bases forming salts which are called *Sulpho-
naphthalates*—*Phil. Trans. for* 1826.

Paranaphthaline and Idrialine—Compounds of carbon and hy-
drogen closely allied to the preceding. The former is obtained from
coal tar; the latter from a mineral from the quicksilver mines at Id-
ria in Carniola.—*Ann. de Chim. et de Phys.* 1.

Camphogen or Camphene.—This name is applied to a compound of car-
bon and hydrogen obtained by Dumas in distilling a peculiar sample
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of turpentine. It is colourless, limpid, volatile, inflammable, and possessed of the characteristic odour of the essence of turpentine. It is supposed to be the basis of camphor.

Citrene.—A compound of carbon and hydrogen, which has received this name from its being the essential and almost sole ingredient of the volatile oil of lemons.

Mixed Combustible Gases from moist Charcoal, Alcohol, Ether, Coal, Oil, Tallow and Wax—Fire Damp.

The vast variety of æriform products obtainable by the exposure of moistened charcoal, of alcohol or ether, of oil, tallow, wax, resin or coal, to a heat a little above ignition, have been ascertained to be mixtures of the hydrurets of carbon already described, with occasionally a portion of carbonic oxide and other gases. Of these products the gases from coal and oil are of the most importance, in consequence of their widely extended use in artificial illumination.

Coal gas.—By submitting coal to distillation in an iron retort, besides a portion of tar and a solution of carbonate of ammonia, which condense in a liquid form, a large quantity of permanent gas is evolved. This gas is very variable in its composition and properties, not only when prepared from different coals, but from the same kind of coal under different circumstances.—*Henry, Phil. Trans.* 1808 *and* 1820.

Coal gas, as generally procured, has a very disagreeable odour, arising from sulphuretted hydrogen, and perhaps a little sulphuret of carbon ; but these may be removed by passing it through lime suspended in water, by agitation. The specific gravity of the purified gas varies from 0·450 to 0·700. A large quantity of an impure carbon, called coke, is found in the retorts, after the extraction of the gas.

It is scarcely possible to assign the quantity of gas, which ought to be obtained from a given weight of coal, but it may be considered as an approach to a general average to state, that 112lbs. of good coal are capable of giving from 450 to 500 cubit feet of gas, of such quality that half a cubic foot per hour is equivalent to a mould candle of six to the pound, burning during the same space of time.—*Henry's Chem.* i. 453.

Oil Gas.—Oil, by being allowed to trickle into a red hot retort, half filled with coke or pieces of brick to increase the heated surface, is decomposed, and yields a large quantity of gas, which is much richer in carburetted hydrogen than coal gas, and is, therefore, much better fitted for purposes of illumination. Its specific gravity varies from 0·800 to 0·950. It contains no admixture of sulphuretted hydrogen, and requires no purification. It is, however, more expensive than the coal gas. See *an Essay by Drs. Turner and Christison in the Edin. Phil. Jour.* xiii. 1.

Gas from Rosin.—It has been ascertained, by Mr. Daniell, that rosin, by peculiar treatment, yields an abundance of gas, equal in quality to that from oil, and at about one fourth of the expense ; its smell moreover is much less offensive than that of either coal or oil gas, and it has been introduced with success in several large establishments in England.—*L. U. K.*

Fire Damp.—The fire damp of coal mines was proved by an analysis

of Dr. Henry, [*Nicholson's Jour.* xix. 149.] to be indentical in composition, with light carburetted hydrogen. This gas often issues in large quantity from between beds of coal, and by collecting in mines, owing to deficient ventilation, gradually mingles with atmospheric air, and forms an explosive mixture. The first unprotected light which then approaches, sets fire to the whole mass, and a dreadful explosion ensues. These accidents are now, however, comparatively rare, owing to the employment of the *Safety-Lamp* of Davy, of which the annexed figure is a representation. A is a cylinder of wiregauze securely fastened to the brass rim B, which screws upon C, the cistern containing the oil. The whole is protected and rendered convenient for carrying by the frame and ring D. A wire bent at the top passes through the cistern containing the oil, and enables the miner to trim the wick of the lamp without taking off the gauze.

The principle upon which this instrument affords a protection against the explosions of fire damp has been adverted to in the remarks upon the causes which modify combustion (page 66). It may be further illustrated by taking a piece of wire-gauze having about thirty meshes to the square inch, and bringing it gradually down upon the flame of an alcohol lamp or a jet of coal gas, when the appearances represented in the figure will be exhibited. The flame is so far cooled as to be extinguished, and it is thus prevented from traversing the wire-gauze. The inflammable matter of the flame, however, passes through the gauze and may be rekindled by a lighted taper, on the upper side.
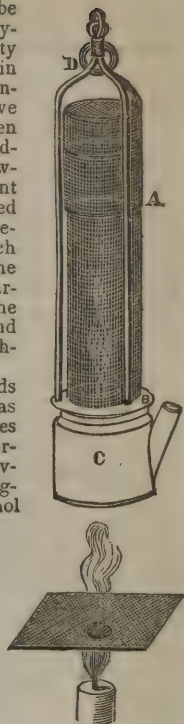
REFERENCES. *For the methods of separating the various impurities from Coal Gas, see the papers of Dr. Henry, in the Phil. Trans. for* 1808 *and* 1820, *or Ann. of Phil.* xiv.—*An abstract of the analytical part of these papers is given in the 2d volume of his Elements of Chemistry. The Essay of Drs. Turner and Christison, above quoted, contains much practical information concerning Oil and Coal Gas. The article Gas Lights, in the Supplement to the Encyclopædia Britannica. Daniel's patent for preparing gas from rosin, in Brande's Jour. N. S.* i. 217. *The Treatises on Gas Lights, by Mr. Accum and Mr. Peckston, and by Dr. Cooper. Davy on the Safety-Lamp for coal miners, Lond.* 1818, *containing a full history of the Lamp, and of the chemical researches connected with it. Dumas, Traité de Chimie appliquée aux Arts.*

OLEFIANT GAS AND CHLORINE.

Chloride of Hydrocarbon.—Atom. Num. 49·35—*Symb.* $(2H+2C)+Cl$.

SYN. *Hydrocarburet of Chlorine. Chloric Ether.*
Discovered by the Dutch chemists; but its true nature was first ascertained by Dr. Thomson, [*Mem. Wernerian Soc.* 1,] and more fully eludicated by M. M. Robiquet and Colin.—*Ann. de Chim. et de Phys.* i. and ii.

PROPERTIES. When pure it is a colourless volatile liquid, of a peculiar sweetish taste and ethereal odour; has a specific gravity at 64° of 1·247; boils at 148° F. and may be distilled without change; is decomposed by passing its vapour through a red hot porcelain tube, being resolved into charcoal, bihydruret of carbon, (light carburetted hydrogen,) and muriatic acid gas.

PREPARATION. This compound may be obtained, as before stated, by allowing a mixture of chlorine and olefiant gases to remain at rest. The oily liquid which is generated is to be washed with water and then distilled from chloride of calcium, when the compound is obtained in its pure and dry form.

OLEFIANT GAS AND BROMINE.

Bromide of Hydrocarbon. — *Atom. Num.* 92·26—*Symb.* $(2H+2C)+Br$.

Discovered by M. Serullas.—*Ann. de Chim. et de Phys.* xxxiv. 95.

PROPERTIES. A colourless liquid, heavier than water, very volatile, of a penetrating, ethereal odour, and of a very sweet taste, which it communicates to water in which it is placed, in consequence of being slightly soluble in that liquid; it is solid at a temperature between 21° and 23° F. and then resembles camphor.

PREPARATION. According to Serullas, this compound is best obtained by bringing two parts of bromine into contact with one of iodide of hydrocarbon; the products being bromide of iodine and bromide of hydrocarbon.

OLEFIANT GAS AND IODINE.

Iodide of Hydrocarbon.—Atom. Numb. 140—*Symb.* $(2H+2C)+I$.

Discovered by Mr. Faraday.—*Phil. Trans.* 1821. *Ann. of Phil.* xviii. 104.

PROPERTIES. A solid white, crystalline body, which has a sweet taste and an aromatic odour; it sinks rapidly in boiling sulphuric acid; it is fused by heat and then sublimed without change, condensing into crystals, which are either tabular or prismatic; on exposure to heat it is decomposed and iodine escapes; it burns, if held in the flame of a spirit lamp, with evolution of iodine and some hydriodic acid; it is insoluble in water and in acid or alkaline solutions, but dissolves in alcohol or ether, and crystallizes upon evaporating the solution.

PREPARATION. This compound may be obtained by exposing olefiant gas and iodine contained in the same vessel, to the direct rays of the sun.

CARBON AND NITROGEN.

Nitruret of Carbon, or Cyanogen.[*]—*Atom. Num.* 26—*Symb.* N+2C—
Sp. gr. 1·804 air=1.

Discovered by Gay Lussac, in 1815.—[*Ann. de Chim.* xcv. *and Ann. of Phil.* viii. 37.] Its properties have also since been investigated by Vauquelin.—*Ann. of Phil.* xiii. 430.

PROPERTIES. A colourless gas, with a strong, pungent and very peculiar odour; at the temperature of 45° F. and under a pressure of 3.6 atmospheres, it is a limpid liquid, which resumes the gaseous form when the pressure is removed; it extinguishes burning bodies, but it is inflammable and burns with a beautiful and characteristic purple flame; it is not decomposed by the strongest heat; water, at the temperature of 60° F. absorbs 4.5 times, and alcohol 23 times its volume of the gas. Though a compound body, cyanogen has a great tendency to combine with elementary substances.

Cyanogen is absorbed by water.—The aqueous solution reddens litmus; this, however, is scarcely to be considered as an effect of the gas itself, but is owing to the presence of acids which are generated by the mutual decomposition of cyanogen and water. [*Vauquelin, Ann. of Phil.* xiii. 430.] By long keeping, a strong solution was found by Vauquelin to assume a light amber colour, and to deposit orange yellow crystals, which he proposes to call *subcyanogen.*— *Ann of Phil. N. S.* vi. 98.

It unites with elementary substances.—This property, which is somewhat peculiar in the case of a compound body, is illustrated by heating potassium in cyanogen gas; an energetic action ensues, the metal becomes incandescent, and a *cyanide of potassium* is generated. On the other hand, the affinity of cyanogen for the metallic oxides is comparatively feeble. Hence it can have no claim to the character of an acid.

PREPARATION. Cyanogen does not exist in nature, but may be prepared by the decomposition of the cyanide of mercury, a compound which will be described hereafter.

This substance, well dried, at a temperature below that of boiling water, is put into a small glass retort, or a common test tube, to the open end of which a cork is accurately fitted. Through this is passed a smaller pipe, which may be straight or bent at right angles. The cyanide of mercury is put into the tube, the open end of which is closed by the cork. Heat is now applied; the cyanide first blackens, then liquifies, and the cyanogen comes over in the form of gas, which may be collected over mercury; or its combustibility and the peculiar colour of its flame may be exhibited by bringing a taper into contact with the gas as it issues from the orifice of the pipe.

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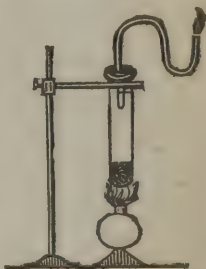
[*] From the Greek *kuanos, blue,* and *gennao, I generate;* because it is an essential ingredient of Prussian blue.

CYANOGEN AND OXYGEN.

Cyanic Acid, of Wöhler.—*Atom. Num.* 34—*Symb.* $(N+2C)+O$.

This acid has a penetrating odour similar to the strongest acetic acid ; it is very pungent, irritating the eyes strongly, and causing pain when applied to the skin ; is very volatile, giving off a vapour which is inflammable and posesses acid properties ; when combined with water, heat is produced, and it is converted into carbonate of ammonia.

Cyanic acid may be obtained in combination with one atom of water, by subjecting to a low red heat, in a small glass retort, the cyanuric acid to be presently noticed. The vapours which are given off are collected in a receiver surrounded by a freezing mixture.

The cyanate of potassa may be readily formed by calcining, at a red heat, equal weights of anhydrous ferrocyanate of potassa and peroxide of manganese. The remaining mass, after being pulverized, is to be boiled with alcohol 86 per cent. pure ; on cooling, the cyanate of potassa separates in small plates resembling the chlorate of potassa.—*Ann. de Chim. et de Phys.* xxvii. 196.

Fulminic Acid.—This acid, which has been obtained in a separate state by Prof. Davy of Dublin, has been shown by Liebig and Gay Lussac to be identical in composition with the cyanic acid, although quite different in its properties. It is one of the ingredients of the fulminating compounds of mercury and silver, which have hence been denominated *Fulminates.*—*Ann. de Chim. et de Phys.* xxiv.

Cyanuric Acid.—(*Cyanic acid of Serullas*).—*Atom. Num.* 129—*Symb.* $3(N+2C)+6O+3H$.

This acid is obtained, according to Serullas, by the action of hot water upon the perchloride of cyanogen ; muriatic acid and a compound of cyanogen, oxygen and hydrogen, are the results. Evaporation expels the muriatic acid, while the cyanuric acid is deposited on cooling in the form of rhomboidal prisms. These crystals are further purified, by a second solution and evaporation. The acid, however, as thus obtained still contains two proportions of water. It has little taste, reddens litmus, and may be boiled in strong nitric or sulphuric acid without decomposition.

The anhydrous cyanuric acid in the form of octahedral crystals with square bases, is obtained by cooling from a hot concentrated solution of the hydrous crystals in sulphuric or muriatic acid. Leibig and Wohler have also ascertained that the substance called pyrouric acid, which sublimes when uric acid is decomposed by heat, is the cyanuric acid. They have, moreover, shown that the latter acid may be obtained by subjecting urea to a temperature of about 600° F. The term *cyan-uric* is applied to this acid in consequence of its close relation to urea and uric acid, joined to the fact that cyanogen is one of its constituents.—*Ann. de Chim. et de Phys.* xli. 225. xliii. 64.

CYANOGEN AND CHLORINE.

There appear to be two distinct compounds of chlorine and cyanogen, which have been termed *Chloride* and *Perchloride of Cyanogen.*

Chloride of Cyanogen.—*Atom. Num.* 61·45—*Symb.* Cl+(N+2C.)

SYN. *Cyanide of Chlorine. Chlorocyanic Acid. Chloride Cyaneux.*
—Berzelius.

Discovered by Berthollet, and subsequently examined by Gay Lussac [*Ann. de Chim.* xcv.] and by Serullas—[*Ann. de Chim. et de Phys. Aug.* 1827,] by whom it was first obtained in a state of purity.

PROPERTIES. Chloride of cyanogen is remarkable in the circumstance of its crystallizing in long slender needles, at the temperature of 0° F. (by this it is separated from portions of other gases, with which it would otherwise be liable to be contaminated ;) it becomes liquid at about 8° or 10° F. and at 68° F. is a gas equivalent to four atmospheres ; in the liquid state it is as limpid and colourless as water ; it has a very offensive odour, irritates the eyes, is corrosive to the skin, and highly injurious to animal life ; reddens vegetable blue colours, and does not explode when mixed either with oxygen or hydrogen gases.

PREPARATION. If cyanide of mercury be mixed with just sufficient water to reduce it to a semi-fluid state, and exposed to the action of gaseous chlorine, in the course of a few hours the colour of the chlorine will disappear, and a gas will be found in its place, which is not absorbable by mercury, but is instantly taken up by water. This is the chloride of cyanogen or chlorocyanic acid. One portion of the chlorine, in this process, expels the cyanogen from the mercury, and forms bichloride of mercury, while another portion combines with the cyanogen and forms the new compound.—*For details, see Henry's or Turner's Chemistry. See also, Gay Lussac in Ann. of Phil.* viii. 47.

Perchloride of Cyanogen.—*Atom. Num.* 96·90—*Symb.* 2Cl+(N+2C.)

SYN. *Chloride Cyanique*—Berzelius.
Discovered by Serullas.—*Ann. de Chim. Aug.* 1828.

PROPERTIES. When carefully purified and dried, it is brilliantly white and crystallizes in needles ; its specific gravity is 1·320 ; it fuses at 284°, and boils at 374° F. ; when kept for some time, it exhales, on opening the bottle, an odour of muriatic acid ; it is sparingly soluble in cold water, but dissolves in hot, though with partial decomposition ; it is extremely poisonous, a single grain having proved fatal to a rabbit.

PREPARATION. The process of Serullas is to pour about 155 grains of pure hydrocyanic acid of Gay Lussac into a bottle containing about 61 cubic inches of dry chlorine. The bottle being closed with a stopper, and exposed to sun-light, the hydrocyanic acid is vaporized ; and after a few hours a colourless liquid is seen on the inner surface of the bottle, having the appearance of water, which becomes thicker and thicker, and finally in about twenty-four hours, sets into a white solid, mixed with shining crystals. The process is one of some delicacy, and requires the observance of several precautions, which are given at length in the original memoir, above referred to.—*Henry*, i. 485.

CYANOGEN AND BROMINE.

Bromide of Cyanogen.—*Atom. Num.* 104·26—*Symb.* Br.+(N+
2C.)

This compound has been obtained by M. Serullas, by a process anal-
ogous to that for preparing chloride of cyanogen. The properties al-
so closely resemble those of that compound, as well as of iodide of cy-
anogen.—*Ann. de Chim. et de Phys.* xxxiv. and xxxv.

CYANOGEN AND IODINE.

Iodide of Cyanogen.—*Atom. Num.* 152—*Symb.* I+(N+2C.)

Obtained by Serullas by heating, in a wide mouthed phial, a mix-
ture of one part iodine and two parts cyanide of mercury, both perfect-
ly dry. When the cyanide of mercury begins to be decomposed, and
the violet vapour of iodine ceases to be produced, the phial is placed
inclined under an inverted bell-shaped glass, the mouth of which is then
closed with a piece of paper or disk of glass. White vapours arise
from the phial, and are condensed in fine cotton-like flocks on the sur-
face of the paper or glass disk. To purify these from some adher-
ing cyanide of mercury, they are resublimed at the gentlest heat ade-
quate to that effect.

The properties of this compound are analogous to those of chloride
of cyanogen.—*Ann. de Chim. et de Phys.* xxvii.

CYANOGEN AND HYDROGEN.

Hydrocyanic or Prussic Acid.—*Atom. Num* 27.—*Symb.*
H+(N+2C.)

Discovered by Scheele in 1782, but, as it was afterwards found, in
solution in water. First procured in a pure state by Gay Lussac.

PROPERTIES. Pure hydrocyanic acid is a limpid and colourless fluid,
of a strong odour, similar to that of peach blossoms; its taste is first
cool, but soon becomes hot and acrid; its specific gravity at 45° F., is
0·7058; it is highly volatile; boils at 79° F., and at zero congeals; a
drop of it placed on a piece of glass becomes solid, because the cold
produced by the evaporation of one portion is so great as to freeze the
remainder; it unites with alcohol and water in all proportions; is
liable to spontaneous decomposition, and cannot be preserved for any
length of time, even when out of contact of air, in well stopped bottles;
is highly poisonous; reddens litmus paper feebly, and combines with
bases forming salts, which are called *Hydrocyanates* or *Prussiates.*

PREPARATION. The best process for preparing hydrocyanic acid, is
that proposed by Vauquelin. It consists in filling a narrow tube placed
horizontally, with fragments of cyanide of mercury, and causing a cur-
rent of sulphuretted hydrogen gas to pass slowly along it.—The instant
that gas comes in contact with the cyanide, double decomposition en-
sues, the sulphur of the gas combines with the metal, forming black
sulphuret of mercury, and the cyanogen, which is liberated, unites with
the hydrogen. The acid may be expelled by a very gentle heat, and
collected in a receiver kept cool by ice.

This acid may also be obtained by moistening the cyanide of mercury with muriatic acid, and distilling at a low temperature. This is the process adopted at Apothecaries' Hall in London.—*See Webster's Brande.*

TESTS. The presence of free hydrocyanic acid is easily recognized by its odour. When in combination, it may be detected by adding to the liquid supposed to contain it, a solution of green vitriol, throwing down the protoxide of iron by a slight excess of pure potassa, and after exposure to the air for four or five minutes, acidulating with muriatic or sulphuric acid, so as to redissolve the precipitate. Prussian blue will then make its appearance, if hydrocyanic acid had been originally present.

As the hydrocyanic acid is sometimes administered with criminal designs, the chemist may be called on to search for its presence in the stomach after death. This subject has been investigated experimentally by M. M. Leuret and Lassaigne, and the process they have recommended is the following. The stomach or other substances to be examined are cut into small fragments, and introduced into a retort along with water, the mixture being slightly acidulated with sulphuric acid. The distillation is then conducted at a temperature of 212° F., the volatile products collected in a receiver surrounded with ice, and the presence of hydrocyanic acid in the distilled matter, tested by the method above mentioned. These gentlemen found that hydrocyanic acid may be thus detected two or three days after death; but not after a longer period. The disappearance of the acid appears to be owing partly to its volatility, and partly to the facility with which it undergoes spontaneous decomposition.—*Journal de Chimie Medicale, &c.* xii. 561.—*Turner.*

ACTION ON THE ANIMAL ECONOMY. Pure hydrocyanic acid is a powerful poison, producing insensibility and convulsions, which are speedily followed by death. A single drop of it placed on the tongue of a dog causes death in the course of a very few seconds; and small animals, when confined in its vapour, are rapidly destroyed. On inspiring the vapour, diluted with atmospheric air, headache and giddiness supervene; and for this reason the pure acid should not be made in close apartments during warm weather. The distilled water from the leaves of the *Prunus lauro-cerasus* owes its poisonous quality to the presence of this acid. Its effects are best counteracted by diffusible stimulants, and of such remedies, solution of ammonia appears to be the most beneficial.

This acid in its diluted form is sometimes employed in medical practice to diminish pain and nervous sensibility. It may be procured of any strength by dissolving cyanide of mercury in water, and transmitting a current of sulphuretted hydrogen gas through the solution till the whole of the cyanide is decomposed; which may be known by the filtered liquid remaining colourless and transparent when mixed with a solution of sulphuretted hydrogen.

REFERENCES. *Gay Lussac's experiments on Prussic Acid, Ann. de Chim.* xcv. 136, *or Ann. of Phil.* vii. 350, viii. 37, 108. *Porrett's Memoir on Prussic Acid, Trans. Lond. Soc. of Arts, &c.* xxvii. 89. *For details concerning its action on the human system, and its medical employment, see Magendie's Formulary—also Beck's Med. Juris. ; Christison on Poi-*

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sons; and Randolph on the deleterious effects of Hydrocyanic acid, Amer.
Med. Recorder, iv. 456.

HYDROCYANIC ACID AND AMMONIA.

Hydrocyanate of Ammonia.

This salt crystallizes in cubes or in very small prisms. Its volatility
is such, that at a temperature of 72° F. its vapour supports a column of
upwards of 15 inches of mercury; and at 97° F., it is equal to the
pressure of the atmosphere. Dr. Thomson finds, that when prussian
blue is exposed to a red heat in a copper tube, and the products received-
ed over mercury, the glass receiver is coated with transparent crystals
of this salt. The solution of this salt precipitates several metallic
solutions not affected by hydrocyanic acid, which, according to Scheele,
acts only on nitrates of silver and mercury, and on carbonate of iron.
—*Ann. of Phil.* xv. 394. *Henry's Chem.* i. 480.

CYANOGEN AND SULPHUR.

Cyanide of Sulphur, or Sulphuret of Cyanogen.

This compound was first formed by Lassaigne. Into a small glass
balloon he puts a little cyanide of mercury finely pulverized, and pours
upon it half its weight of bichloride of sulphur. At the end of 14 or
15 days of exposure to day-light, the balloon being closed so as to ex-
clude air, a minute quantity of crystals rise to the upper part of the
balloon, which are the acid in question.

Like the sulphocyanic acid, with which it may possibly be identical,
it forms crimson coloured salts, with the peroxide of iron.—*Ann. de
Ch. et de Ph. Oct.* 1828. *Henry,* i. 500.

A *Bisulphuret of Cyanogen* has been obtained in a separate state by
Liebig.

Sulphocyanic Acid.—*Atom. Num.* 59—*Symb.* H+(N+2C+2S).

Syn. *Anthrazothionic Acid.*—Grotthuss.

This acid was discovered in the year 1808, by Mr. Porrett, who as-
certained that it is a compound of sulphur, carbon, hydrogen, and ni-
trogen, and described it under the name of *Sulphuretted Chyazic Acid.*
It is now more commonly called *Sulphocyanic Acid,* and its salts are
termed *Sulphocyanates.*

Properties. A transparent liquid, which is either colourless or has
a slight shade of pink; odour somewhat similar to that of vinegar;
the strongest solution of it which Mr. Porrett could obtain, had a spe-
cific gravity of 1·022; it boils at 216·5° F. and at 54·5° crystallizes in
six-sided prisms, reddens litmus paper, and forms neutral compounds
with alkalies; its presence, whether free or combined, is easily detect-
ed by a persalt of iron, with the oxide of which it unites, forming a
soluble salt of a deep blood-red colour; with the protoxide of copper
it yields a white salt, which is insoluble in water.

Preparation. This acid is obtained by mixing so much sulphuric
acid with a concentrated solution of the sulphocyanate of potassa as
is sufficient to neutralize the alkali; and then distilling the mixture,

an acid liquor collects in the recipient, which is sulphocyanic acid dissolved in water, and sulphate of potassa remains in the retort.

REFERENCES. *The memoirs of T. Von Grotthuss, Vogel, and R. Porrett Jun. in Ann. of Phil.* xiii. 39, 89, 101, 356.

CARBON AND SULPHUR.

Bisulphuret of Carbon, or Alcohol of Sulphur.

Discovered in 1796 by Professor Lampadius, who regarded it as a compound of sulphur and hydrogen, and termed it *Alcohol of Sulphur.* Its true nature was first pointed out by Clement and Desormes.

PROPERTIES. A transparent colourless liquid, remarkable for its high refractive power ; specific gravity 1·272 ; has an acid, pungent, and somewhat aromatic taste, and a nauseous and very fetid smell ; is very volatile, and boils at the common atmospheric pressure at a temperature not exceeding 110° F. ; owing to its volatility, it may be employed for producing an intense degree of cold : it has never been congealed by the lowest artificial temperature ; is highly inflammable, and burns with a blue flame, emitting copious fumes of sulphurous acid ; dissolves readily in alcohol and ether, and is precipitated from the solution by water ; dissolves sulphur, phosphorus and iodine ; decomposes chlorine, with the formation of chloride of sulphur ; combines with the alkalies and alkaline sulphurets, forming compounds which Berzelius calls *Carbosulphurets.*

PREPARATION. This compound may be obtained by heating in close vessels the native bisulphuret of iron, (iron pyrites,) with one-fifth of its weight of well dried charcoal ; or by transmitting the vapour of sulphur over fragments of charcoal heated to redness in a tube of porcelain. The compound, as it is formed, should be conducted by means of a glass tube into cold water, at the bottom of which it is collected. To free it from moisture and adhering sulphur, it should be distilled at a low temperature in contact with the chloride of calcium.

SECTION VI.

BORON.

Atom. Num. 8—*Symb.* B.

First obtained by Sir H. Davy in 1808, by the action of Voltaic electricity on boracic acid. Subsequently in greater quantity by Gay Lussac and Thenard, by heating boracic acid with potassium.

PROPERTIES. Boron is a dark olive-coloured substance, which has neither taste nor smell, and is a non-conductor of electricity ; insoluble in water, alcohol, ether and oils ; does not decompose water whether hot or cold ; bears an intense heat in close vessels, without fusing, or undergoing any other change, except a slight increase of density ; its specific gravity is about twice as great as that of water ; it may be exposed to the atmosphere at common temperatures without

change, but if heated to 600° F., it suddenly takes fire, oxygen gas disappears, and boracic acid is generated ; it experiences a similar change when heated in nitric acid, or with any substance that yields oxygen with facility.

PREPARATION. In addition to the above methods of preparing boron, that of Berzelius should be noticed as the easiest and most economical method of producing it. This consists in heating the potassium in contact with the fluoborate of potassa.—*Berzelius, Traité de Chim.* i. 361. *Ann. of Phil.* xxvi. 128.

BORON AND OXYGEN.

Boracic Acid.—Atom. Num. 24—*Symb.* $2O+B$—*Sp. gr.* 1·479 water $=1$.

SYN. *Homberg's sedative Salt.*

PROPERTIES. Boracic acid has the form of thin white scales, is destitute of smell, and nearly so of taste ; is sparingly soluble in water, and the solution reddens vegetable blue colours ; and, what is very remarkable, it renders tumeric paper brown like the alkalies. [*Faraday.*] It is soluble in alcohol, and communicates a beautiful green colour to its flame ; fuses when heated, and gives off its water of crystallization to the amount of 43 or 44 parts in the hundred, and is converted into a hard colourless transparent glass, which is anhydrous boracic acid, the hydrous or crystalline acid being supposed to consist of one proportion of dry acid and two of water.

PREPARATION AND NATIVE STATE. As a natural product, this acid is found in the hot springs of Lipari, and in those of Sasso in the Florentine territory. It is a constituent of several minerals, among which the *datholite* and *boracite* may in particular be mentioned. It occurs much more abundantly under the form of borax, a native compound of boracic acid and soda. It is prepared for chemical purposes by adding sulphuric acid to a solution of purified borax in about four times its weight of boiling water, till the liquid acquires a distinct acid reaction. The sulphuric acid unites with the soda ; and the boracic acid is deposited, when the solution cools, in a confused group of shining scaly crystals. It is then thrown on a filter, washed with cold water to separate the adhering sulphate of soda and sulphuric acid, and still further purified by solution in boiling water and re-crystallization.— But even after this treatment it is apt to retain a little sulphuric acid, and on this account, when required to be absolutely pure, should be fused in a platinum crucible, and once more dissolved in hot water and crystallized.

REFERENCES. *Gay Lussac and Thenard on the decomposition and recomposition of Boracic Acid, Jour. de Phys.* 1808, *and Repert. of Arts,* 2d ser. xiv. 408. *Robiquet on the preparation of Boracic Acid from Tincal and the waters of Lakes in Tuscany, Ann. de Chim. et de Phys.* ii. 203, *and Repert. of Arts,* 2d ser. xxxvi. 123. *Faraday on the action of Boracic Acid on Turmeric, Brande's Jour.* vi. 152.

BORON AND CHLORINE.

Bichloride of Boron.—Atom. Num. 78·9—*Symb.* 2Cl+B—*Sp. gr.* 3·942.
air=1.

SYN. *Chloride Borique.*—Berzelius.

Boron burns with considerable splendour in chlorine gas. The
product Berzelius finds to be a new gas, which may be freed from
excess of chlorine by standing over mercury. [*Berzelius, Traité de
Chim.* i. 365-6. *Ann. of Phil.* xxvi. 129.] It smokes in the atmosphere
like fluoboric acid gas ; is rapidly absorbed by water, is soluble also
in alcohol ; unites with ammoniacal gas, forming a fluid volatile sub-
stance.

The combination of these two elements has been better effected by
Despretz, by passing chlorine over boruret of iron, and also by trans-
mitting the same gas, deprived of water, over charcoal and boracic
acid, ignited together in a porcelain tube.—*Phil. Mag. and Ann.* i.
469.

BORON AND FLUORINE.

Fluoboric Acid, or Fluoride of Boron.

SYN. *Fluoride Borique.*—Berzelius.

Discovered in 1810 by Gay Lussac and Thenard. Its true compo-
sition does not yet appear to be understood.

PROPERTIES. Fluoboric acid gas is colourless, has a penetrating
pungent odour, and extinguishes flame on the instant; its specific
gravity, according to Dr. Thomson, is 2·3622; it reddens litmus pa-
per as powerfully as sulphuric acid, and forms salts with alkalies
which are called *Fluoborates ;* it has a singular affinity for water.—
When it is mixed with air or any gas which contains watery vapour,
a dense white cloud appears, which is a combination of water and
fluoboric acid gas. From this circumstance, it affords an exceedingly
delicate test of the presence of moisture in gases. Fluoboric acid gas
is rapidly absorbed by water. According to Dr. John Davy, water
absorbs 700 times its volume. Caloric is evolved during the absorp-
tion, and the water acquires an increase of volume. The saturated
solution is limpid, fuming, and very caustic. On the application of
heat, part of the gas is disengaged ; but afterwards the whole solution
is distilled.

This acid does not act on glass, but attacks animal and vegetable
substances with great energy; converting them, like sulphuric acid,
into a carbonaceous substance. According to Berzelius, when in a
certain state of dilution, part of the fluoboric acid and water mutually
decompose each other, with formation of boracic and hydrofluoric
acids. The latter he supposes to unite with undecomposed fluoboric
acid, forming what he has called *Hydrofluoboric Acid.* [*Traité de
Chim.*] A different view, however, is maintained by Gay Lussac and
Thenard.

PREPARATION. This gas may be obtained by subjecting to strong
heat, in an iron tube, a mixture of one part of dry boracic acid, and
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two parts of powdered fluor spar. It may also be procured by mixing one part of vitrified boracic acid, and two of fluor spar, with twelve parts of strong sulphuric acid, and heating the mixture gently in a glass retort. [*Dr. John Davy, Phil. Trans. for* 1812.] When thus prepared, however, it contains fluosilicic acid, according to Berzelius, in considerable quantity ; and Dr. Thomson detected in it traces of sulphuric acid. The gas may likewise be formed by the action of hydrofluoric acid on a solution of boracic acid.

REFERENCES. *Thenard, Traité de Chim. Berzelius, in Ann. of Phil.* xxvi. 122.

BORON AND SULPHUR.

Sulphuret of Boron.

SYN. *Sulfide Borique.*—Berzelius.

This compound may be formed, according to Berzelius, by igniting boron strongly in the vapour of sulphur, and the combination is accompanied with the phenomena of combustion. The product is a white opaque mass, which is converted by the action of water into sulphuretted hydrogen and boracic acid ; and the liquid becomes milky at the same time from the deposition of sulphur.— *Ann. of Phil.* xxvi. 129. *Berzelius,* i. 365.

SECTION VII.

SELENIUM.

Atom. Num. 40—*Symb.* Se—*Sp. gr.* 4·3 water=1.

Discovered by Berzelius, in 1818.

PROPERTIES. Selenium, at common temperatures, is a brittle solid, of a brown colour and metallic fracture ; it has neither taste nor smell ; when pounded, the particles stick together, and its powder has a deep red colour ; it melts at a few degrees above the boiling point of water, and when warm is very ductile, and may be drawn into fine threads, which are red by transmitted, but grey by reflected, light ; it boils at a temperature of about 600° F. and condenses either in opaque metallic drops, or, when large vessels are used, in flowers of the colour of cinnabar ; its vapour has a deep yellow colour ; when heated in the flame of a candle, urged by a current of air from a blow-pipe, it emits a strong smell of horse-radish.

When selenium was first discovered it was regarded, by Berzelius, as a metal ; but, since it is an imperfect conductor of caloric and electricity, it more properly belongs to the class of simple non-metallic bodies. It is still very rare, and many accomplished chemists have never yet had an opportunity of seeing it. I shall, therefore, be quite brief in the account of it and of its compounds.

NATIVE STATE AND EXTRACTION. In the process for obtaining sulphuric acid at Fahlun, in Sweden, from a natural combination of sulphur and iron, called pyrites, it was observed that a reddish mass was deposited, which in burning gave out a peculiar odour. The principal portion of the mass was sulphur; but it was mixed with a very

minute quantity of a substance, to which Berzelius afterwards gave the name of selenium. The process by which it was extracted is given at length, in *Ann. of Phil.* xiii. 403. The improved method of M. Lewenau is also given in the 24th volume of that work. It has since been discovered in the volcanic rocks of Lipari; in several varieties of sulphur; and in sulphuric acid made with pyrites obtained from the isle of Anglesea. [*Ann. of Phil.* xxiv. *and* xxv.] Selenium has also been discovered by M. Henry Rose, in several minerals from the Eastern Hartz, united with lead, cobalt, copper and mercury—[*Ann. de Ch. et de Phys.* xxix. 113,] and Stromeyer and Haussman have analyzed a seleniuret of lead from the Laurence mine at Clausthal.—*Ann. of Phil.* xxvi. 233.

REFERENCES. *On this substance and its compounds, see a detailed notice in Berzelius, Traité de Chim.* ii. 397.

SELENIUM AND OXYGEN.

There appear to be three distinct compounds of selenium and oxygen, though the first of these is not yet well understood.

Oxide of Selenium.—Atom. Num. 48 ?—Symb. $O + Se$?

Oxide of Selenium is formed by heating selenium in a close phial with common air, which acquires a very strong smell of horse-radish. Water agitated with this air, imbibes the odour of the gas, and reddens litmus feebly, but this appears to be owing to the production of a small quantity of selenious acid.

Oxide of selenium is a colourless gas, which is very sparingly soluble in water, and does not possess any acid properties. Its composition has not yet been determined, but it probably contains an atom of each of its elements. Berzelius, to whom we are indebted for most that is known concerning it, does not seem to have yet obtained it in a perfectly pure state.—*Ann. de Chim. et de Phys.* ix. 176.

Selenious Acid.—Atom. Num. 56—Symb. $2O + Se$.

Discovered by Berzelius.

PROPERTIES. A white crystalline substance, having a sour and slightly burning taste; it is very soluble, both in water and in alcohol; it is readily decomposed by all substances which have a strong attraction for oxygen. If sulphurous acid be passed into its solution, pure selenium will be thrown down in the state of a red powder, and sulphuric acid formed; it may likewise be precipitated by the immersion of plates of zinc or polished iron; it combines with bases and forms *Selenites*.

PREPARATION. This acid is most conveniently prepared by digesting selenium in nitric or nitro-muriatic acid, till it is completely dissolved. On evaporating the solution to dryness, a white residue is left which is selenious acid. By increase of temperature, the acid itself sublimes, and condenses again unchanged, in long four-sided needles. It attracts moisture from the air, whereby it suffers imperfect liquefaction.

REFERENCE. *Berzelius*, ii. 405.

Selenic Acid.—Atom. Num. 64—*Symb.* 3O+Se.

Discovered by Professor Mitscherlich, and described in *Ann. de Chim. et de Phys. Sept.* 1827, *and in Edin. Jour. of Science*, viii. 294.

PROPERTIES. A colourless liquid, which may be heated to 536° F. without sensible decomposition, but at 554° F. is resolved into oxygen and selenious acid ; its specific gravity, when freed as completely as possible from water, is 2·625 ; but even when of this density, it still contains 15·75 of water in 100 of acid ; like sulphuric acid it evolves great heat when suddenly diluted. When heated with muriatic acid, it affords chlorine and selenious acid, and like aqua regia, dissolves gold.

Selenic acid dissolves iron and zinc with a disengagement of hydrogen ; copper with an evolution of selenious acid, and gold, but not platinum. In its affinities for bases it is a little inferior to sulphuric acid, but its compounds, (seleniate of baryta, for example,) are not entirely decomposed by the latter acid.

PREPARATION. This acid may be prepared by fusing nitrate of potassa with selenium, with selenious acid or with a seleniuret, such as that of lead, freed from earthy impurities by muriatic acid. The residue, amounting to about one-third of the whole, is mixed with an equal weight of nitrate of soda, and projected, by little at once, into a red-hot crucible. The lead is oxidized, and the selenium is converted into selenic acid, which combines with the soda. The purification of the seleniate of soda involves many details, which may be found in the original memoir above quoted.—[*See also Turner's Chemistry.*] The last step of the process consists in decomposing seleniate of lead in solution, by sulphuretted hydrogen, which precipitates sulphuret of lead, leaving the selenic acid in such a state as to be purified by ebullition.

SELENIUM AND CHLORINE.

Chloride of Selenium.

Selenium absorbs chlorine gas, and becomes hot and forms a brown liquid, which, by an additional quantity of chlorine, is converted into a white solid mass. This is stated by Berzelius to be a compound of muriatic and selenic acids, but it is probably composed of chloride of selenium and selenious acid. It has not yet been accurately separated into its component parts, for when heat is applied, both substances are sublimed.—*Henry*, i. 424.

SELENIUM AND BROMINE.

Bromide of Selenium.

This compound is obtained, according to Serullas, by causing selenium to fall, in small portions, upon bromine. They combine with violence, and with the disengagement of heat. When cold, the mass is solid, of an orange colour, and soluble in water.—*Berzelius*, ii. 419.

SELENIUM AND HYDROGEN.

Hydroselenic Acid.—Atom. Num. 41—*Symb.* H+Se.

SYN. *Seleniuretted Hydrogen Gas. Selenide Hydrique.* — Berzelius.

Discovered by Berzelius and found to be analogous to sulphuretted hydrogen.

PROPERTIES. A colourless acid, with an odour at first similar to that of sulphuretted hydrogen, but it afterwards irritates the lining membrane of the nose powerfully, excites catarrhal symptoms, and destroys, for some hours, the sense of smelling ; it is absorbed freely by water, forming a colourless solution which reddens litmus paper, and gives a brown stain to the skin. The acid is soon decomposed by exposure to the atmosphere ; for the oxygen of the air unites with the hydrogen of the hydroselenic acid, and selenium, in the form of a red powder, subsides.

All the salts of the common metals are decomposed by hydroselenic acid. The hydrogen of that acid combines with the oxygen of the oxide, and a seleniuret of the metal is generated.

PREPARATION. This gas is disengaged by the action of muriatic acid upon a concentrated solution of an hydroseleniate. It may also be procured by heating the seleniuret of iron in muriatic acid. By the decomposition of water, oxide of iron and hydroselenic acid are generated ; and while the former unites with muriatic acid, the latter escapes in the form of gas.

SELENIUM AND SULPHUR.

Sulphuret of Selenium.—Atom. Numb. 64—*Symb.* 1½S+Se.

When sulphuretted hydrogen gas is conducted into a solution of selenic acid, an orange-coloured precipitate subsides, which is a sulphuret of selenium. It fuses at a heat a little above 212° F. and at a still higher temperature may be sublimed without change. In the open air it takes fire when heated, and sulphurous, selenious, and selenic acids are the products of its combustion. The alkalies and alkaline hydrosulphurets dissolve it. Nitric acid acts upon it with difficulty ; but nitro-muriatic acid converts it into sulphuric and selenic acids.— *Ann. of Phil.* xiv. *Berzelius,* ii. 415.

SELENIUM AND PHOSPHORUS.

Phosphuret of Selenium.

The phosphuret of selenium may be prepared in the same manner as the sulphuret of phosphorus; but as selenium is capable of uniting with phosphorus in several proportions, the compound formed by fusing them together can hardly be supposed to be of a definite nature. This phosphuret is very fusible, sublimes without change in close vessels, and is inflammable. It decomposes water gradually when digested in it, giving rise to seleniuretted hydrogen and one of the acids of phosphorus.— *Ann. of Phil.* xiv. *Berzelius,* ii. 417.

CHAPTER VIII.

METALS.

GENERAL PROPERTIES OF THE METALS.

The metals constitute the most important class of substances with which we are acquainted. They are characterized,—by being all conductors of caloric and electricity,—by appearing, when combined with oxygen, chlorine, iodine, sulphur, or similar substances, and subjected to the action of galvanism, at the negative pole of the battery,—by being quite opaque,—by being good reflectors of light, and by possessing a peculiar lustre, denominated the *metallic lustre*.

The number of metals at present known to chemists, is forty-two. Some of these were known and made use of in the earliest ages of the world, whereas others were discovered during the present century. The following table designates the names of the metals and the date of the discovery, so far as this is known, together with the name of the discoverer.

Names of Metals.	Discoverers.	Date of Discovery.
1. Gold, 2. Silver, 3. Iron, 4. Copper, 5. Mercury, 6. Lead, 7. Tin,	Known to the Ancients.	
8. Antimony,	Described by Basil Valentine,	15th cent.
9. Zinc,	Described by Agricola,	1520.
10. Bismuth,	First mentioned by Paracelsus,	16th cent.
11. Arsenic, 12. Cobalt,	Brandt,	1733.
13. Platinum,	Wood, Assay Master, Jamaica,	1741.
14. Nickel,	Cronstedt,	1751.
15. Manganese,	Gahn and Scheele,	1774.
16. Tungsten,	MM. D'Elhuyarts,	1781.
17. Tellurium,	Müller,	1782.
18. Molybdenum,	Hielm,	1782.
19. Uranium,	Klaproth,	1789.
20. Titanium,	Gregor,	1791.
21. Chromium,	Vauquelin,	1797.
22. Columbium,	Hatchett,	1802.
23. Palladium, 24. Rhodium,	Dr. Wollaston.	1803.
25. Iridium,	Descotils and Smithson Tennant,	1803.
26. Osmium,	Smithson Tennant,	1803.
27. Cerium,	Hisinger and Berzelius,	1804.

Names of Metals.	Discoverers.	Date of Discovery.
28. Potassium, 29. Sodium, 30. Barium, 31. Strontium, 32. Calcium,	Sir H. Davy,	1807.
33. Cadmium,	Stromeyer,	1818.
34. Lithium,	Arfwedson,	1818.
35. Silicium, 36. Zirconium,	Berzelius,	1824.
37. Aluminum, 38. Glucinum, 39. Yttrium,	Wohler,	1828.
40. Thorium,	Berzelius,	1829.
41. Magnesium,	Bussy,	1829.
42. Vanadium,	Sefstrom,	1830.

Metallic Lustre.—This property depends upon the opacity of the metals, in consequence of which the light is reflected by their surface more completely than it is from other bodies. The metals, however, differ in their lustre. Platinum possesses it in the highest degree; after which, according to Leslie, are silver, mercury, gold, copper, tin, and lead.

Colour.—The colours of the metals are almost all, either white or some shade of bluish or greyish white : gold, copper, and titanium alone present shades of yellow or orange. The true colour of a metal may be ascertained, by reflecting the light from one to another plate of the same metal two, three, four, or more times.—*Dumas*, ii. 6.

Specific Gravity.—Great specific gravity was formerly considered as a distinctive character of the metals ; none being known previous to the decomposition of the alkalies, less than six times heavier than water. But the metallic bases of most of the alkalies and earth are lighter than that liquid. Indeed the heaviest and the lightest solids are now included in the list of metals.

The following is a table of the specific gravity of the principal metals compared to water as 1.

1. Platinum,	-	-	21·00	9. Nickel, -	-	-	8·27
2. Gold, -	-	-	19·25	10. Manganese,	-	-	8·01
3. Mercury,	-	-	13·56	11. Iron, -	-	-	7·78
4. Lead, -	-	-	11·35	12. Tin, -	-	-	7·29
5. Silver, -	-	-	10·47	13. Zinc, -	-	-	7·00
6. Bismuth,	-	-	9·82	14. Antimony,	-	-	6·70
7. Copper, -	-	-	8·89	15. Sodium, -	-	-	0·972
8. Cobalt, -	-	-	8·53	16. Potassium,	-	-	0·865

Malleability.—Metals are said to be *malleable*, which admit of being beaten into thin plates or leaves, by the hammer. If when subjected to the process of the hammering, they break, they are said to be *brittle*.

Malleability is one of the most useful properties of the metals. It belongs to the following, in the order in which they are arranged :

1 Gold,	5 Cadmium,	9 Iron,
2 Silver,	6 Platinum,	10 Nickel,
3 Copper,	7 Lead,	11 Palladium,
4 Tin,	8 Zinc,	12 Potassium.

Sodium and frozen mercury are also malleable.

Gold surpasses all metals in malleability. When perfectly pure it can be beaten into leaves—not more than the 1-282,000ths of an inch in thickness. A grain of it can be beaten out into so fine a leaf as to cover 50 square inches of surface and contain two millions of visible points ; but the gold which covers the silver-wire used in making gold lace, is spread over a surface twelve times as great.

The leaves of gold are so thin, that if formed into a book, 1,500 would occupy only the space of a single leaf of common paper ; and an octavo volume of an inch thick, would have about as many pages as the books of a well stocked ordinary library containing 1,500 volumes of 400 pages in each.—*Arnott.*

Ductility.—Metals are said to be *ductile*, when they possess the property of being drawn out into wires. The only ones which are remarkable in this respect, are gold, silver, platinum, iron, and copper, though some others possess ductility in an inferior degree. Dr. Wollaston devised a method by which gold-wire may be obtained so fine, that its diameter shall be only 1-500ths of an inch; and that 550 feet are required to weigh one grain. He obtained a platinum wire so small that its diameter did not exceed 1-30,000ths of an inch. [*Phil. Trans.* 1813.] It is somewhat surprizing that the ductility and malleability of the same metals, are not always in proportion to one another. Iron, for example, cannot be made into fine leaves, but it may be drawn into very small wires.

Tenacity.—By *tenacity* is meant the power of supporting weight without breaking. According to the experiments of Guyton-Morveau, iron in point of tenacity, surpasses all the other metals. The results which he gives in the *Ann. de Chim.*, are as follows :

The diameter of each wire was 0·787ths of a line.

Iron wire supports,	-	-	-	-	549·25 pounds.
Copper, -	-	-	-	-	302·278
Platinum,	-	-	-	-	274·320
Silver, -	-	-	-	-	187·137
Gold, -	-	-	-	-	150·753
Zinc, -	-	-	-	-	109·540
Tin, -	-	-	-	-	34·630
Lead, -	-	-	-	-	27·621

Hardness.—The metals differ considerably from each other in hardness. Among those which are most hard, may be ranked titanium, manganese, iron, nickel, copper, zinc ,and palladium. Gold, silver, and platinum, are softer than these; lead is still softer, and potassium and sodium yield to the pressure of the fingers.

Structure. Many of the metals have a crystalline structure, though this is by no means common to all. Crystals may be most easily procured from those metals which fuse at a low temperature. Bismuth offers the finest illustration, as it affords when fused and treated in the manner described when noticing the crystallization of sulphur, beau-

tiful and regular cubic crystals. Arsenic crystallizes in regular tetra-
hedrons, and titanium in long slender filaments or prisms. It may be
also observed that some metals, as gold, copper, and silver, occur natu-
rally in the form of crystals.

Native state of Metals.—When metals occur in the earth in a state
of purity, they are called *native.* To this class, however, belong only
those which have a feeble attraction for oxygen, as gold, silver, plati-
num, mercury, &c. Commonly they are, as it is termed, *mineralized,*
by oxygen, sulphur, or arsenic; and they are sometimes also found in
the state of salts. From these compounds the pure metal is extracted
by various processes, which, when conducted on a large scale, consti-
tute the branch of chemistry denominated *metallurgy.* But the pro-
cesses for determining the purity of metals and other mineral substan-
ces by experiments made in a small way, are sometimes termed the
art of assaying.

Action of Heat.—The metals are all susceptible of fusion by heat, but
the temperatures at which they liquify are very various. Mercury is
fluid at common temperatures, and requires to be cooled to —39° F. be-
fore it congeals. Potassium melts at 136° F. and sodium at 200°;
tin at 430°; lead at 500°; and zinc at about 700°. Silver, gold and
copper require a bright cherry red heat; iron, nickel and cobalt, a
white heat; manganese and palladium, an intense white heat. Mo-
lybdenum, uranium, tungsten and chromium are only imperfectly ag-
glutinated at the highest temperatures of our furnaces; and titanium,
cerium, osmium, iridium, rhodium, platinum and columbium require
the intense heat of the oxyhydrogen blow-pipe or that of the voltaic
electricity.

The metals also differ greatly in their *volatility.* Mercury, cadmi-
um, arsenic, tellurium, potassium, sodium and zinc are volatile at a red
heat and may be easily distilled in close vessels. But many others
may be exposed to the most intense heat of a wind furnace without
being changed into vapour. It is probable, however, that all of them
could be converted into vapour if raised to sufficiently high tempera-
tures, as gold and platinum, which are among the most fixed, evapo-
rate when exposed to the intense heat of the focus of a burning lens.

Action of the Electric Fluids.—The metals are excellent conductors
of electricity, surpassing in this respect all other bodies. When their
surface is sufficiently extensive to carry off the fluid, they undergo no
change; but when the contrary is the case, the fluid penetrates the in-
terior, heats, and in some instances, melts and volatilizes them. Such
is the effect produced by the discharge of a powerful galvanic or Ley-
den battery upon very fine wires, or thin plates of any metal, and this
is more apparent if the experiment be performed in contact with air,
when the combustion is more or less vivid, and the flame assumes dif-
ferent colours. For example, iron burns with a very vivid white
light, zinc with a whitish or yellowish white light, silver with a green,
&c.

Action of Oxygen Gas.—Oxygen gas, in a dry state is absorbed by
but few of the metals at ordinary temperatures. Among these are po-
tassium, barium, lithium, strontium, calcium, and the bases of the
earths. But at an elevated temperature, it acts upon almost all the
metals, except platinum, silver, gold, palladium, iridium, and rhodi-
um. In some cases the union of the metals with oxygen is so rapid as

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to give rise to all the phenomena of real combustion. Zinc burns with a brilliant flame when heated to full redness in the open air, and iron emits vivid scintillations on being inflamed in an atmosphere of oxygen gas. The same will apply to tin, cadmium, arsenic, antimony, tellurium and bismuth ; although the combustion of tin, antimony, and bismuth, is the most feeble.

The product either of a slow or rapid oxidation of a metal, when heated in the air, has an earthy appearance, and was termed a *calx* by the older chemists, the process of forming it being called *calcination.*

There are other processes sometimes employed for oxidating the metals, as by *deflagration ;* that is by mixing them with nitrate or chlorate of potassa, and projecting the mixture into a red hot crucible, or by digestion in nitric or nitro-muriatic acid.

Some metals combine with oxygen only in one proportion ; but the greater number of them combine with it in two or three proportions. The resulting compounds are either *oxides* or *acids.* With the exception of arsenic, the metals all produce oxides by combination with oxygen. But many of them which, when combined with one atom of oxygen, produce oxides, form acids when combined with two or three atoms of oxygen. This occurs in the case of chromium, tungsten, molybdenum and vanadium.

When a metallic oxide is deprived of its oxygen and brought to the metallic state, it is said to be *reduced,* and the operation itself is called *reduction.* This reduction may be effected in several ways, viz.

1. By heat alone.—The oxides of gold, silver, mercury and platinum, may be decomposed by subjecting them to a red heat, when the oxygen escapes in the form of gas.

2. By the combined action of heat and combustible matter.—The reduction is effected in this case by the superior attraction of the combustible matter for oxygen. Thus when oxide of lead is heated with charcoal, carbonic acid gas is evolved and metallic lead obtained.— Upon the same principle a current of hydrogen gas passed over the oxides of copper or iron heated to redness in a porcelain tube, causes the reduction of the metal, while water is at the same time formed. The metals also are sometimes employed for the same purpose, and it sometimes happens that a metal which at a low temperature decomposes a metallic oxide, may have its oxide decomposed by that metal at a higher temperature. Thus oxide of iron is reduced by potassium at a very low temperature ; while potassa is reduced by iron when the heat is very intense.

3. By the voltaic battery.—This in some cases effects the reduction of an oxide which resists the preceding agents : as in the case of baryta and strontia.

4. By the action of various agents on metallic solutions.—A neutral solution of gold when exposed to the sun's rays has a film of gold formed on the side turned to the light, which gradually increases in thickness. Phosphorous acid when added to a liquid containing oxide of mercury, deprives the oxide of its oxygen, metallic mercury subsides, and phosphoric acid is generated. Certain metals also introduced in the metallic state into saline solutions of some others, deprive the latter

of their acid and oxygen and precipitate them in a metallic state.*
Thus mercury added to a solution of nitrate of silver throws down metallic silver, and oxide of mercury is dissolved by the nitric acid. In these cases the reduced metal is usually obtained in the state of fine powder or cohering together in a porous mass. Occasionally, however, it is met with in a solid malleable state, and even in the form of regular crystals. Thus it is stated that in the copper pits of Anglesea, where iron is thrown in to reduce the copper from its solutions, malleable and crystallized copper has often been obtained. And it has been ascertained by Wach that whenever the process proceeds with sufficient slowness, the metal is deposited in this form. A very convenient method of accomplishing this object is to sew up the metal in two or three folds of bladder, and so immerse it in the solution to be precipitated, when the metal will be deposited on the outer surface in a massive state.—*Johnston's Report.*

The action of atmospheric air upon the metals is analogous, though less powerful than that of oxygen.

Those metals which are speedily acted upon by common air and oxygen, are also generally susceptible of decomposing water; some of them rapidly, others slowly. There are some metals which are not acted upon by air deprived of moisture, nor by water deprived of air; but moist air, or water containing air, effects their oxidation; this appears to be the case with iron.—*Hall, in Brande's Jour.* vii. 55.

Water combines with some of the metallic oxides, and produces *hydrated oxides,* or *metallic hydrates.* In these, the relative proportion of water is definite. Some are easily decomposed by heat, as hydrate of copper; others retain water even when heated to redness, as hydrate of potassa.

Every acid, with few exceptions, is capable of uniting with each of the metallic oxides, and of forming compounds, in which the separate qualities of the component principles are no longer apparent, and are hence called *neutral* salts.

Ammonia also combines with several of the metallic oxides, forming what are called *Ammoniurets.* Some of these are crystalline compounds, and those formed by the union of ammonia with the oxides of gold, silver and platinum, detonate when heated.

Action of Chlorine.—Chlorine has a powerful attraction for metallic substances. It combines readily with many of the metals at common temperatures, and in some cases this combination is attended with the evolution of light. Thus when powdered zinc, antimony or arsenic, is thrown into a vessel of chlorine gas, the metal is instantly inflamed. Indeed the affinity of chlorine for the metals is even superior to that of oxygen; for if chlorine gas be brought into contact with lime, magnesia, baryta, strontia or potassa, at a red heat, oxygen is liberated, and a chloride of the metal is formed. The elements of these com-

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* In a series of experiments which I performed for the purpose of ascertaining whether the process of crystallization was at all influenced by magnetism, in which nothing was observed to confirm the views of Murray, I found that the process of metallic precipitation was greatly influenced by solar light. Glass tubes bent in the form of the letter V, and containing solution of nitrate of silver, and metallic mercury, always had the largest and most numerous blades of silver in that leg of the tube which was turned to the light.

pounds are so strongly united, that no temperature hitherto tried can separate them.

Although the metallic chlorides may, in most cases, be formed by the direct action of chlorine upon the metals, they are perhaps more generally obtained by evaporating a solution of the muriate of a metallic oxide to dryness, and applying heat until all the water is driven off.

When a true metallic chloride is dissolved in water, there are two views which may be taken of the changes that occur. Either the chloride may dissolve as such in water, or a decomposition of that fluid may ensue,—the chlorine seizing the hydrogen and forming muriatic acid, while the metal may compose with the oxygen of the water an oxide capable of saturating the newly formed acid. In this way, a chloride may be converted, by the action of water, into a true muriate. The latter appears to be the most correct view, especially in those cases where the chloride contains a metal, which, *per se*, decomposes water ; as potassium, sodium, &c. On this subject see *Ann. of Phil.* xvii. ; where the opinions entertained by different chemists regarding the action of the chlorides on water, have been collected together by Mr. Richard Phillips ; and who has adduced satisfactory evidence, that, in many instances, chlorides, by solution in water, are converted into muriates.

The same course of reasoning will apply to the metallic iodides, bromides and fluorides.

Chlorine, in a dry state, does not unite with the pure oxides of the metals ; but if these last contain water, they absorb variable proportions of it. These compounds, however, possess very little permanency, and none of them can be heated to redness without decomposition.

Action of Bromine.—The affinity of bromine for metallic substances is intermediate between chlorine and iodine ; for while chlorine disengages bromine from its combination with metals, the metallic iodides are decomposed by bromine. The bromides are formed in the same manner as the chlorides; that is by the action of bromine upon the metals, or by evaporating solutions of metallic oxides in hydrobromic acid to dryness.

Action of Iodine.—Iodine has a strong attraction for the metals, and most of the compounds which it forms with them, can sustain a red heat, in close vessels, without decomposition. It is, however, inferior in the force of its affinity to either oxygen or chlorine. Chlorine when brought into contact with the iodides at high temperatures, effects their decomposition in the same manner as it does that of the oxides. Iodine separates oxygen only from potassa, soda, protoxide of lead, and the oxide of bismuth, when heated to redness. In all other cases the iodides are decomposed by exposure to oxygen gas, at the temperature of ignition.

According to Gay Lussac, when the vapour of iodine is conducted over red hot lime, baryta or strontia, oxygen is not disengaged, but an iodide of these oxides is formed. If this be correct, it differs in this respect from chlorine. Iodine, however, is allowed not to combine with any other oxide under the same circumstances.

Action of Fluorine.—As this substance has not hitherto been obtained in a separate state, we are unacquainted with the nature of its action on the metals. There is, however, every reason to suppose

that the compounds obtained by the evaporation of certain solutions of metallic oxides in hydrofluoric acid, are in reality fluorides of the metals.

Action of Hydrogen.—Hydrogen combines with few metals. The only compounds, at present known, are those of potassium, zinc, arsenic and tellurium. These are either solid or gaseous. They are generally obtained by liberating hydrogen in contact with the metals.

Action of Nitrogen.—Two compounds of nitrogen with metals are now known to exist, viz. the nitrurets of potassium and sodium. These are obtained by treating the metals with ammoniacal gas.— *Thenard, Traité de Chim.*

Action of Sulphur.—There are but few metals which are incapable of combination with sulphur. These *sulphurets*, as they are termed, are often found native, and appear to have been known in the earliest ages of the world. They have, therefore, been studied with great care by many chemists.

In general, metals form the same number of sulphurets as of oxides and chlorides, and the same law of composition applies to them. Thus a proto-sulphuret consists of one atom of sulphur and one atom of the metal; a deuto-sulphuret of two atoms of sulphur and one of the metal, &c.

All the metallic sulphurets are solid and inodorous. All, especially the artificial ones, are brittle, even though the metals which enter into their composition are ductile. All are insipid, except those of the four first classes. Some, as the sulphurets of iron, lead, antimony, &c. have a metallic lustre; others, as the sulphuret of mercury, are destitute of it. Most of them are susceptible of crystallization. Their specific gravity is always less than that of the metals which they contain, unless indeed the metal itself is lighter than sulphur, as potassium and sodium.

In those cases where the metal itself possesses the power of decomposing water at ordinary temperatures, the sulphuret of the metal at this same temperature, possesses a similar property. A portion of gaseous sulphuretted hydrogen is at the same time liberated and a hydrosulphuretted oxide remains. This takes place with the sulphurets of sodium, potassium, &c.

An opinion was formerly quite prevalent among chemists that many of the metallic sulphurets were compounds of sulphur and a metallic oxide. This was supposed to be particularly the case with the fixed alkalies and alkaline earths. The more recent investigations of Berthier and Berzelius, however, have demonstrated that the metallic bases of these agree with the common metals in their disposition to unite with sulphur. It is now certain that whether a sulphate be decomposed by hydrogen or charcoal, or sulphur ignited with an alkali or alkaline earth, a metallic sulphuret is always the product. It is lamost equally certain that there are no definite compounds of sulphur and the metallic oxides.

The metallic sulphurets may be obtained in one or other of the following ways.

1. By heating the metal in combination with sulphur in a covered crucible.

2. By mixing sulphur with the oxide of a metal, and exposing the mixture to heat.

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3. By depriving the neutral sulphates of the oxygen which they contain, through the agency of heat and combustible matter.

4. By the action of sulphuretted hydrogen upon the metallic salts.

Action of Phosphorus.—The compounds of phosphorus and the metals have not yet been very accurately examined, and for the information we possess concerning them we are chiefly indebted to the researches of Pelletier. Phosphorus has heretofore been combined with only twenty-one metals, though it is probable that, like sulphur, it is capable of uniting with all. Pelletier supposed that it combines only in one proportion with a metal, but this opinion is now abandoned; it is most probably subject to the same laws of combination as sulphur and selenium.

All the metallic phosphurets are solid, inodorous, brittle, and tasteless, except those of the metals which decompose water at the ordinary temperature, and give rise to caustic oxides; most of them are crystallizable and have a brilliant metallic lustre.

Many of the metallic phosphurets are, wholly or in part, decomposed by high temperatures, and those of the bases of the fixed alkalies and alkaline earths are decomposed by water. Thus when phosphuret of potassium is thrown upon water, protoxide of potassium is formed and phosphuretted hydrogen is liberated, being known by its inflammation when coming in contact with the air.

None of the metallic phosphurets have hitherto been found in nature. They may be artificially prepared in several ways.

1. By bringing phosphorus either solid or in vapour, in contact with metals at high temperatures.

2. By mixing phosphate of lime and charcoal with the metal and exposing the mixture to heat in a covered crucible.

3. By passing a current of phosphuretted hydrogen through solutions of certain metallic salts in water; during this process water is formed and the phosphuret is precipitated in the form of flocks.

The remarks which have been heretofore made, concerning the compounds of sulphur and the metallic oxides, will apply to phosphorus. It is very doubtful whether there are any definite compounds of phosphorus and these oxides;—although it is asserted, by some chemists, that phosphurets of lime and baryta may be made by conducting the vapour of phosphorus over those earths at a red heat.

Action of Carbon.—Most of the metals which have been reduced by charcoal retain a variable, though usually a very small quantity of it. And contrary to the idea formerly maintained, definite compounds are in this manner formed. The most important of these are cast iron and steel, which will be particularly noticed under the head of iron.

Action of Cyanogen.—Cyanogen, as already stated, (p. 189,) has an affinity for metallic substances. Few of the Cyanides, however, have been hitherto obtained in a separate state, excepting those of potassium, mercury, silver and palladium. The three latter are readily decomposed by heat. Cyanogen also unites with some of the metallic oxides.

Action of Boron.—There is but little known concerning the boru-

rets. According to M. Descotils, however, they are solid, brittle, insipid and inodorous ; and they are formed by calcining strongly a mixture of charcoal, boracic acid and filings of iron or platinum, formed into a paste with oil or fat. In this process the oxygen of the boracic acid unites with the carbon, producing carbonic oxide, which is disengaged ; at the same time the boron combines with the iron or platinum, forming a boruret.

Action of Selenium.—It is probable that selenium will unite with most of the metals. The combination is effected by bringing selenium in contact with metals at a high temperature, or by adding hydroselenic acid to metallic solutions. The seleniurets have a close resemblance to sulphurets.

Actions of Metals upon each other.—The union of a metal with one or more metals, is termed an *alloy ;* and each alloy is distinguished by the name of the metals which constitute it. Thus an *alloy of lead and tin* is a combination of lead and tin. The name *amalgam*, however, is applied to combinations of mercury with the metals. Thus when we speak of an amalgam of this or that metal, we express a compound of that metal with mercury.

The study of the metallic combination has not yet received that attention which its importance seems to demand. It is probable that each metal is capable of combining in one or more proportions with every other metal, though the number of alloys at present known, does not exceed one hundred and forty. But it may be observed that there are some circumstances which will prevent the number of these compounds from reaching the limit which theory may designate. Among these may be ranked, in particular, the very different fusibility and volatility of the metals ; causes which oppose obstacles to the formation of alloys.

Chemists very generally agree that the metals unite with each other in every proportion, in the same manner as sulphuric acid or alcohol and water ; and that their combination is not governed by those laws which apply to the oxides, acids and other definite compounds. An opposite opinion, however, has been maintained by Berzelius, as well as by Dalton. Potassium, the former observes, gives, with mercury, two crystallized compounds, one of which contains twice as much potassium as the other. The *Arbor Dianæ* is a definite compound of silver and mercury. When zinc and copper are distilled together, a certain quantity of zinc comes over, but the rest cannot be raised by heat. From a fused mixture of antimony, iron and copper with much tin, metallic crystals separate on cooling, containing fixed proportions of the component metals. Indeed, as Dr. Turner remarks, it is possible that the variety of proportions is rather apparent than real, arising from the mixture of a few definite compounds with one another, or with uncombined metals, an opinion not only suggested by the mode in which alloys are prepared, but in some measure by observation. Still, however, the present state of our knowledge does not warrant us in considering all the alloys as chemical compounds.

The *alloys* resemble the metals in most of their physical properties. They are solid at ordinary temperatures, except the alloy of potassium and sodium, and the amalgams in which mercury predominates ; they are opaque ; possess the metallic lustre ; are good conductors of electricity and caloric ; and are more or less crystalline in struc-

ture. They often differ in some respects from the metals of which they are composed. The colour of an alloy is sometimes different from that of its constituents, of which brass is a remarkable example. The hardness of a metal is in general increased by being alloyed, and for this reason its elasticity and sonorousness are frequently improved. The malleability and ductility of metals, on the contrary, are usually impaired by combination. Alloys formed of two brittle metals are always brittle ; and an alloy composed of a ductile and a brittle metal is generally brittle, especially if the latter predominate. An alloy of two ductile metals is sometimes brittle.

The density of an alloy is sometimes less, sometimes greater, than the mean density of the metals of which it is composed.

The fusibility of metals is greatly increased by being alloyed. Thus pure platinum, which cannot be completely fused in the most intense heat of a wind furnace, forms a very fusible alloy with arsenic.

The tendency of metals to unite with oxygen is considerably augmented by being alloyed. This effect is particularly conspicuous when dense metals are liquefied by combination with quicksilver, and is manifestly owing to the loss of their cohesive power. Lead and tin, for instance, when united with mercury, are soon oxidized by exposure to the atmosphere ; and even gold and silver combine with oxygen, when the amalgams of those metals are agitated with air.— The oxidability of one metal in an alloy appears in some instances to be increased in consequence of a galvanic action. Thus Mr. Faraday observed, that an alloy of steel with 100th of its weight of platinum was dissolved with effervesence in dilute sulphuric acid, which was so weak that it scarcely acted on common steel ;—an effect which he ascribes to the steel in the alloy being rendered positive by the presence of the platinum.— *Turner.*

A number of metallic alloys are found native ; among these may be mentioned those of arsenic, with bismuth, with antimony, with nickel, with iron, and with silver ; of iron and nickel ; of silver and antimony ; silver and lead ; nickel and cobalt, besides a great many others, especially those which are found in the mines of platinum and tellurium.

Alloys may be prepared artificially, by heating in a crucible the metals of which they are composed. When fusion has been effected they are to be carefully mixed, without which, especially if the metals are of different specific gravities, the alloy will not be homogeneous. If one or both the metals are volatile, care should be taken not to subject the alloy to too high heat. A modification of this process is required for the preparation of alloys of potassium and sodium, which cannot be effected in contact with air. For this purpose we should employ a tube closed at one end ; the potassium or sodium is put into the lower part and covered with the metal with which it is to be alloyed ; the tube is then to be heated until both the metals are fused.

Amalgams are either liquid or solid ; liquid, when the mercury predominates, and generally solid when the quantity of mercury is less than that of the metal to which it is united. There, is however, considerable variation in this respect. Thus the amalgam formed of 80 parts of mercury and 1 of sodium is solid, while that formed of 15 parts of mercury and 1 of tin is liquid. In the liquid state, the amalgams resemble mercury, except that they flow less easily ; in their solid state they are brittle. They are very generally of a white colour. They

are all susceptible of crystallization, and of being formed in constant proportions. To effect this it is necessary to dissolve, by heat, a certain quantity of a metal in mercury, and to suffer the combination to become cold; it then separates into two portions, the one solid and crystallized, the other liquid.

All the amalgams can be decomposed by a red heat. Almost all the liquid amalgams which contain an easily oxidized metal are decomposed by the contact of air; this is particularly the case with the amalgams of potassium, barium, strontium and calcium.

The amalgams may be prepared by bringing mercury in contact with the metals in a state of minute division. It is well known, that mercury instantly combines with gold and assumes a white colour. These combinations, however, may be more advantageously formed by the aid of heat; indeed the amalgams of zinc and antimony can only be properly formed by melting these metals, and throwing into them the metals slightly heated by little at a time.

Some amalgams may also be formed by the action of the voltaic battery. Thus when a globule of mercury is placed in contact with the negative wire, during the process of decomposing potassa by galvanism, an amalgam of potassium is formed.

Some of these combinations are of great importance in the arts.

CLASSIFICATION OF THE METALS.

The study of the metals ought not to be conducted in an arbitrary manner. They may be conveniently divided into the following natural groups or classes, viz:

CLASS I. *Metals which, when combined with oxygen, form the fixed alkalies.*

Potassium,   Sodium,   Lithium.

These metals have such a powerful attraction for oxygen, that at common temperatures they decompose water at the moment of contact, and are oxidized; while at the same time, the hydrogen of the water is liberated in a gaseous form. The resulting oxides are distinguished by their causticity and solubility in water, and by their possessing properties which are denominated alkaline.

CLASS II. *Metals which, when combined with oxygen, form alkaline earths.*

Barium,   Strontium,   Calcium,   Magnesium.

These, like the preceding, decompose water at ordinary temperatures. The resulting oxides are called *Alkaline Earths;* because, while in their appearance they resemble the earths, they are similar to the alkalies, in having a strong alkaline reaction with test paper, and in neutralizing acids. The three first are strongly caustic, and baryta and strontia are soluble in water to a considerable extent.

CLASS III. *Metals which, when combined with oxygen, form earths.*

Aluminum,   Glucinum,   Yttrium,
Zirconium,   Silicium,   Thorium.

The oxides of these metals constitute the well known substances denominated pure *Earths*. They are white, and of an earthy appearance; in their ordinary state, are quite insoluble in water, and do not affect the colour of litmus or turmeric paper. As salifiable bases, they are quite inferior to the alkaline earths; and one of them, namely silica, is considered by some chemists, as an acid, for reasons which will hereafter be developed.

CLASS IV.   *Metals, which decompose water only when their temperature is raised to redness.*

Manganese,	Iron,	Zinc,
Tin,	Cadmium,	Nickel.
Cobalt,		

CLASS V.   *Metals, which do not decompose water at any temperature, and the oxides of which are not reduced to the metallic state by the sole action of heat.*

These may be ranged under two heads:

1. Those which, when combined with oxygen, form acids.

Arsenic,	Molybdenum,	Chromium,
Vanadium,	Tungsten,	Antimony,
Uranium,	Columbium,	Cerium.
Titanium,	Tellurium,	

2. Those which do not form acids.

| Bismuth, | Copper, | Lead. |

CLASS VI.   *Metals, the oxides of which are decomposed by a red heat.*

Mercury,	Silver,	Gold,
Platinum,	Palladium,	Rhodium.
Osmium,	Iridium,	

CLASS I.

METALS WHICH WHEN COMBINED WITH OXYGEN FORM THE FIXED ALKALIES.

SECTION I.

POTASSIUM.

Atom. Num. 39·15—*Symb.* Po—*Sp. gr.* 0. 865.

Discovered by Sir H. Davy in 1807, and particularly examined by him, and by Gay Lussac and Thenard.

PROPERTIES. Potassium is solid at ordinary temperatures; at 70° F. it is somewhat fluid, though its fluidity is not perfect, till it is heated to 150° F.; it sublimes at a red heat without undergoing any change, provided the air be completely excluded; at 50° it is ductile and malleable, and of the consistency of soft wax; at 32° it becomes a hard and brittle solid; in colour and lustre it is precisely similar to mercury; is a good conductor of electricity and caloric; has a great affinity for oxygen gas, oxidizing rapidly when exposed to air or by contact with fluids containing oxygen, and decomposing water with the disengagement of heat and light; burns when heated in the air with a brilliant white light; it burns spontaneously in chlorine with intense brilliancy.

Potassium has a great affinity for oxygen.—When exposed to the air or brought into contact with fluids which contain oxygen, this metal is rapidly oxidized. On this account it must be preserved, either in glass tubes hermetically sealed, or under the surface of liquids, such as naphtha, of which oxygen is not an element.

It decomposes water.—When potassium is thrown upon the surface of water it decomposes that liquid with great rapidity, and the hydrogen gas evolved carrying with it small particles of the metal, takes fire in the air, and communicating the combustion to the potassium, the whole burns with a kind of explosion, emitting a red light.

If a globule of potassium be placed on ice, it instantly burns with a bright flame and a deep hole is made in the ice, filled with a fluid which is found to be solution of potassa.

The production of an alkali by the action of water upon potassium is most satisfactorily shown by dropping a globule of the metal upon moistened paper, which has been tinged with turmeric. At the moment when the globule comes into contact with the paper, it burns and moves rapidly, as if in search of moisture, leaving behind it a deep reddish brown trace, and acting upon the paper exactly like dry caustic potassa.

Exp. The following is an instructive experiment: Take a piece of potassium, wrap it up in a small piece of paper, and introduce it

quickly into a glass test tube, inverted in a small vessel of infusion of blue cabbage, the tube being filled with the same liquid. The metal will immediately rise to the top, and the moment the water reaches it through the paper, part of it will be decomposed, the oxygen combining with it and forming potassa, which changes the blue of the infusion to a green; while an equivalent portion of hydrogen gas is found in the tube and may be inflamed by a lighted taper.

But perhaps the most striking illustration of the deoxidizing power of potassium is exhibited by its action on carbonic acid. When heated in contact with that gas, it takes fire, and by uniting with its oxygen, forms potassa, while the liberated carbon is deposited in the form of charcoal.

It acts powerfully upon iodine and sulphur.—Put three or four grains of iodine into a common test tube, throw a grain of potassium upon it, and hold the sealed end of the tube for a second or two in the flame of a spirit-lamp. The iodine and potassium immediately combine with the evolution of light and heat. The result is similar when sulphur is substituted for the iodine. Some care is necessary in performing these experiments.

PREPARATION. Sir H. Davy first obtained this metal, although in small quantity, by subjecting moistened hydrate of potassa to the action of a powerful voltaic battery, the oxygen of both the water and potassa passed over to the positive pole, while the hydrogen of the former and metallic potassium appeared at the negative. Gay Lussac and Thenard procured a larger supply by fusing the hydrate of potassa, and allowing it to flow over turnings of iron heated to whiteness in a gun-barrel.

The process by which potassium is most easily prepared, is that first pointed out by Curaudau, subsequently improved by Brunner, and somewhat modified by Wohler. It consists in subjecting to a very strong heat in an iron pot or bottle, a mixture of potassa and charcoal prepared by exposing cream of tartar to a red heat in a large earthen or iron crucible, till no more gas is disengaged. The potassium thus procured, usually contains a minute quantity of carbon, from which it may be freed by distillation in a green glass or iron retort.

REFERENCES. *Sir H. Davy's Bakerian Lecture, Phil. Trans.* 1808, *Repert. of Arts,* 2d ser. xiii. 123, 175. *Gay Lussac and Thenard's improved method, Recherches Phys. Chim.* i. 74. *Brunner's process, Brande's Jour.* xv. 279. *Wohler, Brande's Jour.* xxii. 206. *Detailed directions for preparing potassium may also be found in Berzelius' Traité de Chim.; and in Henry's and Reid's Chemistry.*

POTASSIUM AND OXYGEN.

Potassium unites with oxygen in two proportions, forming the *Protoxide,* and the *Peroxide.*

Protoxide of Potassium.—*Atom. Num.* 47.15—*Symb.* O+Po.

SYN. *Vegetable Alkali—Potassa or Potash.*

PROPERTIES. A white solid, very caustic, heavier than potassium, changing vegetable blues to green; fusible at a heat below redness, and bears the highest heat without decomposition; very deliquescent,

and hence very soluble in water; absorbs oxygen at a high tempera-
ture and passes into the state of peroxide; attracts moisture and car-
bonic acid from the air, and is converted into a carbonate; it cannot
then be wholly deprived of its water by the most intense heat, having
formed with it a solid *hydrate of potassa*.

NATIVE STATE. Potassa occurs in nature as a constituent of differ-
ent minerals and in certain organized bodies. It is found in considera-
ble quantities in the minerals *felspar* and *mica*, from which, indeed,
Fuchs has proposed to prepare potash for commercial purposes. It is
also contained in the ashes of vegetables, but in these cases it requires
a subsequent process to render it pure.

Hydrate of Potassa.—Atom. Num. 58·15—*Symb.* $(O+Po)+(O+H.)$

SYN. *Lapis Causticus Potassæ. Potassa fusa.*—Lond. and Edin.
Phar.

PROPERTIES. Solid at common temperatures; fuses at a heat rather
below redness, and assumes a somewhat crystalline texture on cooling;
highly deliquescent, and requires about half its weight of water for so-
lution; soluble likewise in alcohol; destroys all animal textures, and
hence employed in surgery as a caustic; when in solution, forms the
aqua potassæ of the Pharmacopœias, which possesses properties similar
to the hydrate.

PREPARATION OF ANHYDROUS AND HYDROUS POTASSA. The protoxide of
potassium is always formed when potassium is put into water, or ex-
posed to dry air or oxygen gas. By the first process, even when the
solution is evaporated to dryness and exposed to a red heat, it retains
a portion of water; by the second, it is anhydrous. The anhydrous
oxide may also be obtained, according to Berzelius, by fusing one part
of potassium with 1·4 of hydrate of potassa; the water of the hydrate
is decomposed, hydrogen gas is disengaged, and 2·3 parts of anhydrous
potassa are procured.

The aqueous solution of potassa is prepared by decomposing car-
bonate of potassa by lime. The best process consists in boiling in a
clean iron vessel, carbonate of potassa, with half its weight of pure
quick lime, in water. The lye is strained through clean linen, con-
centrated by evaporation, again strained, and set by in a well stopped
bottle, till it admits of being decanted clear from the sediment. If the
clear solution is evaporated to dryness, and afterwards cast into sticks,
it forms the *potassa fusa*. This may be further purified by alcohol,
which dissolves only the pure hydrate of potassa, and leaves the impu-
rities; the alcohol is then driven off by heat.

According to Dr. Ure, pure potassa for experimental purposes may
most easily be obtained by igniting cream of tartar in a crucible, dis-
solving the residue in water, filtering, boiling with a quantity of quick
lime; and after subsidence, decanting the clear liquid, and evaporat-
ing in a loosely covered silver capsule till it flows like oil, and then
pouring it out on a clean iron plate. A solid white cake of pure hy-
drate of potassa is thus obtained, without the agency of alcohol. It
must be immediately broken into fragments, and kept in a well stopped
phial.

As potassa speedily attracts carbonic acid from the air and becomes
carbonated, the solution must be protected from it as much as possible
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during its filtration. This may be effected by using a funnel with a narrow mouth, which may be easily closed by a cork or stopper, and putting a small tube through the throat of the funnel, placing pieces of quartz or broken glass round it, and covering it with linen, so that while the solution of potassa is dropping into the bottle below, air passes through the tube at the same time from the lower to the upper vessel, and supplies its place. (*Dr. Duncan's Dispensatory.*) A more complicated apparatus has been described by Mr. Donovan.—*Ann. of Phil.* xxvi. 115.

Mr. Dalton has constructed a table showing the quantity of real potassa in solutions of different specific gravities.—*Henry's Chem.* i. 550.

Uses. As potassa absorbs carbonic acid gas rapidly it is sometimes employed for withdrawing that substance from gaseous mixtures. It is also employed as a reagent in detecting the presence of bodies, and in separating them from each other. The solid hydrate, owing to its strong affinity for water, is used for depriving gases of hygrometric moisture, and is well fitted for forming frigorific mixtures.

REFERENCES. *Lowitz's method of obtaining crystallized Potash, perfectly pure, Ann. de Chim. or Rep. of Arts,* 2d ser. x. 225. *Berthollet on the same subject, Rep. of Arts,* 2d ser. xii. 121. *Hope and Phillips on the preparation of Aqua Potassæ, Ann. of Phil.* xvii. 69, 190, xviii. 30.

Peroxide of Potassium.—Atom. Num. 63·15—*Symb.* 3O+Po.

Discovered by Gay Lussac and Thenard.

PROPERTIES. Of an orange colour, caustic, changing infusion of litmus to green; specifically heavier than potassium; fusible below a dull red heat; decomposed by the voltaic battery, but not by heat; when thrown into water, oxygen gas is evolved, and it passes to the state of protoxide; when fused and brought into contact with combustible bodies, they burn vividly in the excess of its oxygen.

PREPARATION. This compound may be prepared by burning potassium in open air, or by heating the metal in a vessel of oxygen gas over mercury, or by exposing nitrate of potassa to a red heat.

REFERENCES. *Thenard, Traité de Chim. Bridges, in North Am. Med. and Surg. Jour.* v. 241.

POTASSIUM AND CHLORINE.

Chloride of Potassium.—Atom. Num. 74·6—*Symb.* Cl+Po.

Long known to chemists under various names, as *Febrifuge salt of Sylvius; Regenerated Sea Salt, &c.*

PROPERTIES. Occurs in cubic crystals, which have a saline and bitter taste, and require three parts of water at 60° F. for solution, and rather a less proportion of boiling water.

PREPARATION. When small pieces of potassium are introduced into

chlorine, intense inflammation takes place, and direct combination ensues. This chloride is also procured by dissolving either hydrate or carbonate of potassa in muriatic acid, and evaporating the solution to perfect dryness.

POTASSIUM AND BROMINE.

Bromide of Potassium.

PROPERTIES. Crystallizes in cubes or in rectangular prisms ; the crystals destitute of water, decrepitating when heated, and entering into fusion without suffering any change ; very soluble in water, and slightly so in alcohol.

PREPARATION. Formed by saturating hydrate of potassa with bromine ; the solution containing bromate of potassa, and bromide of potassium, is evaporated to dryness, and the residuum heated until it ceases to evolve oxygen. The bromate is then converted into bromide.—*Berzelius*, iii. 374.

POTASSIUM AND IODINE.

Iodide of Potassium.—Atom. Num. 165·15—*Symb.* I+Po.

PROPERTIES. Crystallizes in white cubes ; fuses readily when heated, and is volatilized at a temperature below redness ; deliquesces in a moist atmosphere, and is very soluble in water ; soluble also in strong alcohol.

PREPARATION. This compound may be formed by heating potassium in a tube of green glass, with excess of iodine. It may also be obtained by means of heat from the iodate, and by crystallization, from the hydriodate of potassa.

POTASSIUM AND HYDROGEN.

These substances unite in two proportions, the one gaseous, the other solid. The latter contains the least hydrogen.

Hydruret of Potassium.

Discovered by Gay Lussac and Thenard.

PROPERTIES. A grey solid, destitute of metallic lustre ; infusible ; not inflammable either in air or in oxygen gas at common temperatures, but burns vividly at a high one ; totally decomposed when heated in a close vessel, the hydrogen being liberated in the form of gas, the potassium remaining ; when brought into contact with heated mercury, hydrogen gas is evolved, and an amalgam of potassium and mercury is produced.

PREPARATION. This compound may be prepared by heating potassium in hydrogen gas ; and the only difficulty consists in regulating the heat, for a high temperature decomposes the compound.

REFERENCE. *Thenard, Traité de Chim.*

Gaseous Hydruret of Potassium.

Discovered by Sementini.

PROPERTIES. A colourless gas, which, when recently prepared, inflames by the contact of oxygen gas or air, at the ordinary temperature, but at the end of a certain time, loses this property, because it parts with a portion of its potassium.

PREPARATION. According to Sementini, gaseous hydruret of potassium is formed when the hydrate of potassa is subjected to a very high temperature in contact with iron. In this case the oxygen of the water and of the protoxide, combines with the iron, while the hydrogen combines in part with the potassium.— *Thenard, Traité de Chim.*

POTASSIUM AND NITROGEN.

According to Thenard, when potassium is heated in ammoniacal gas, hydrogen gas is liberated, and a *Nitruret of Potassium* is formed, consisting of 100 parts of potassium, and 11·728 of nitrogen.— *Thenard.*

POTASSIUM AND SULPHUR.

Sulphuret of Potassium.—Atom. Num. 55·15— *Symb.* S+Po.

PROPERTIES. Has a reddish colour; fuses below the temperature of ignition, and assumes a crystalline texture on cooling; dissolves in water, being probably converted with the evolution of caloric into hydrosulphuret of potassa.

PREPARATION. Sulphur and potassium readily unite by the aid of heat, with the evolution of so much caloric, that the mass becomes incandescent. The best method, however, of preparing this sulphuret, is to reduce, in a close vessel, sulphate of potassa with charcoal, or to heat the same salt to redness in a glass or porcelain tube, and then pass over it a stream of hydrogen gas.

Besides this protosulphuret, Berzelius has described four other compounds, which he obtained by igniting carbonate of potassa with different proportions of sulphur. These are composed of one equivalent of potassium to two, three, four, and five equivalents of sulphur. See *Berzelius, in Ann. of Phil.* xx. 284— *Trait. de Chim.* ii. 300.

POTASSIUM AND PHOSPHORUS.

Phosphuret of Potassium.

This compound may be formed by the action of potassium on phosphorus with the aid of a moderate heat. It is converted by water into potassa and perphosphuretted hydrogen gas, which inflames at the moment of its formation.

POTASSIUM AND CYANOGEN.

Cyanide or Cyanuret of Potassium.

Potassium acts with great energy upon cyanogen; by the aid of heat it absorbs this gas, with the evolution of light. The compound thus formed is of a yellowish colour; has a very alkaline taste; decomposes water, and gives rise to hydrocyanate of potassa.—*Thenard.*

The process given by Robiquet for procuring this compound, is to subject ferrocyanate of potassa for a considerable time to heat. Prepared in this manner, it is proposed as a substitute for hydrocyanic acid, for medical purposes.—*Magendie's Formulary.*

POTASSIUM AND THE METALS.

The compounds of potassium and the metals are always solid, except when mercury or sodium form a part of them, when they are often liquid. They are white and generally brittle; fusible at a temperature below redness; oxidized by exposure to air; and they decompose water when brought into contact with it.

These compounds are obtained by heating potassium with the different metals in a glass tube; or better, by mixing the metals with about half their weight of carbonized cream of tartar, throwing them into a crucible, covering the mixture with powdered charcoal, luting the cover to the crucible, and calcining for about two hours.—*Serullas, Ann. de Chim.*

Alloy of Potassium and Sodium.—The alloy consisting of 10 parts of potassium and only one of sodium, is liquid at 0° F., and presents the very remarkable property of being lighter than naphtha, or rectified petroleum.

Alloy of Potassium and Bismuth.—This may be obtained by calcining an intimate mixture of 60 parts of carbonized cream of tartar, and 120 parts of bismuth, in the manner before described. This alloy, rich in potassium, scintillates when cut with the scissors, melts and inflames when bruised, and decomposes water. A portion of common charcoal added to it, converts it, according to Serullas, into a pyrophorus, which, when brought into contact with water, inflames, and produces slight detonations.

Alloy of Potassium and Tin.—This may be formed by mixing together 60 parts of tartar, 8 of lampblack, and 100 of oxide of tin. If the quantity of carbon is doubled, a true pyrophorus is produced.

Amalgam of Potassium and Mercury.—When 1 part of potassium and 145 parts of mercury are heated in a glass tube out of contact of air, an amalgam is formed, which resembles mercury in its appearance; it absorbs oxygen at common temperatures, and is converted into pure mercury, and into the oxide of potassium.

Amalgam of potassium can also be obtained by agitating parcels of potassium on a mercurial bath. When potassium is combined with 60 times its weight of mercury, an amalgam is obtained which is solid, very fusible, white, and which crystallizes easily and possesses the same properties as the preceding.

The liquid amalgam when placed in contact with ammonia, or the ammoniacal salts, produces an ammoniacal hydruret of potassium and

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mercury. This compound is quite remarkable for its metallic aspect, its consistency, and its easy decomposition.

A fact noticed by Berzelius concerning the action of amalgam of potassium upon water, deserves to be mentioned. It is, that with water alone it evolves pure hydrogen; but when the water is acid, or charged with sal ammoniac, the hydrogen gas disengaged has the same odour as that obtained by the use of zinc and dilute sulphuric acid.— *Thenard.*

REFERENCES. *Vauquelin, in Ann. de Chim. et de Phys.* vii. 32. *Serullas, same Work,* xxi. 197, *or Repert. of Arts,* 2d ser. xliv. 376. *Thenard, Traité de Chim.*

SALTS OF POTASSA.

Chlorate of Potassa.—Atom. Num. 122·6—*Symb.* (5O+Cl)+(O+Po.)

SYN. *Hyperoxymuriate of Potash. Chlorate Potassique.*—Berzelius.

PROPERTIES. Colourless, crystallizes in four and six-sided scales of a pearly lustre, the primitive form of which, according to Mr. Brooke, is an oblique rhombic prism; soluble in sixteen times its weight of water at 60° F., and in two and a half of boiling water; is quite anhydrous, and when exposed to the temperature of 400° or 500° F., undergoes igneous fusion, and on increasing the heat almost to redness, effervesence ensues, and pure oxygen is disengaged; is decomposed by the stronger acids, and exerts powerful effects on inflammable bodies.

It is decomposed by the stronger acids.—If a few grains of the salt are dropped into a little concentrated sulphuric acid in a wine glass, a strong smell will arise: and if larger quantities of the materials be heated in a retort, a violent explosion sometimes ensues.

Muriatic acid disengages chlorine from chlorate of potassa, and the addition of a few grains of the salt to an ounce measure of the acid, imparts to it the property of discharging vegetable colours.

It exerts powerful effects on inflammable bodies.—To one grain of the powdered salt in a mortar, add about half a grain of phosphorus. The phosphorus will detonate, on the gentlest triture, with a very loud report. The hand should be covered with a glove in making this experiment, and care should be taken that the phosphorus does not fly into the eyes.

Charcoal or sulphur may be substituted for the phosphorus in the above experiment, with the same effects; it requires, however, more powerful triture; or the experiment may be varied by wrapping the mixed ingredients in strong paper or tin foil, and then striking them with a hammer.

This salt may be substituted for nitre in the preparation of gunpowder, but the mixture of the ingredients requires great care, on account of their liability to explode by trituration. When mixed with sulphur it often detonates spontaneously.

PREPARATION. This salt is made by transmitting chlorine gas through a concentrated solution of pure potassa, until the alkali is com-

pletely neutralized. The solution, which, after being boiled for a few minutes, contains nothing but the muriate and chlorate of potassa, is gently evaporated till a pellicle forms upon its surface, and is then allowed to cool. The greater part of the chlorate crystallizes, while the muriate remains in solution. The crystals, after being washed with cold water, may be purified by a second crystallization.

Uses. This salt is employed in the preparation of *percussion powder*, which is merely a gunpowder in which chlorate of potash is substituted for nitre. A little of it is put into a thin copper thimble, and when struck it catches fire and explodes in the piece. The matches which have been sold for inflaming with sulphuric acid, were made by first dipping them in melted sulphur, and then in a composition of chlorate of potassa, sugar and vermilion. Nearly a similar mixture of substances is set on fire by friction with sand paper, and known under the name of Lucifer Matches.

This salt is also used for medicinal purposes in the form of solution and of ointment.—See *Magendie's Formulary*.

References. *For details concerning the preparation of this salt, see Henry's Chemistry*, i. 555. *Berzelius*, iii. 403, *who also describes a Chlorite of Potassa. Fourcroy and Vauquelin's experiments on the explosion of this salt, Ann. de Chim. or Repert. of Arts*, 1st ser. viii. 65. *Cutbush's Pyrotechny*, 74.

Perchlorate of Potassa.—Crystallizes in elongated octahedrons; does not change vegetable colours; requires more than fifty times its weight of water at 60° F. for solution; distilled at 280° F. with an equal weight of sulphuric acid, it yields perchloric acid; when heated to 412° F. oxygen is evolved and chloride of potassium remains.

This salt may be formed by mixing one part of powdered chlorate of potassa with three of sulphuric acid, and cautiously exposing the mixture to heat till it turns white, when we obtain a mixture of bisulphate and perchlorate of potassa. The former being much more soluble than the latter in cold water, their separation may be effected by solution and crystallization.

Iodate of Potassa.—Occurs in small white granular crystals; when projected on hot coals, acts like saltpetre; difficultly soluble in water; when heated to redness, oxygen is given out and is converted into oxide of potassium.

This salt is easily procured by agitating iodine with a solution of potassa; water is decomposed, and gives rise to a soluble hydriodate and a difficultly soluble iodate. When evaporated to dryness and afterwards treated by strong alcohol, the hydriodate is dissolved and leaves the iodate in the form of crystals.

Hydriodate of Potassa—This salt exists only in solution; when dry it is the iodide of potassium. It is very soluble in boiling water, and requires only two-thirds of its weight of water at 60° F. for solution; it is also soluble in alcohol.

This salt is easily obtained by neutralizing hydriodic acid with potassa. But as it is employed quite largely for medicinal purposes, an easier process may be adopted. Perhaps the most eligible of these which have been proposed is to evaporate the mixed iodate and hydriodate of potassa, formed by adding iodine to a warm solution of potassa until the alkali is neutralized, and exposing the dry mass in a plati-

num crucible to a rather low red heat in order to convert the iodate into the iodide of potassium. The fused mass is then dissolved out by water and crystallized.—*Turner's method of preparing Hydriodate of Potassa, Edin. Med. and Surg. Jour., July*, 1825.

Hydrofluate of Potassa.—Crystallizable and deliquescent; its solution, which is alkaline, attacks glass in a day or two and destroys its polish. When the liquid is rendered neutral by acetic acid, it becomes on farther dilution with water strongly acid, and vinegar is set at liberty.

Prepared by supersaturating carbonate of potassa with hydrofluoric acid, evaporating the solution to dryness, and expelling the excess of acid by heat.—*Berzelius, Traité de Chim.* iii. 377.

Bihydrofluate of Potassa.—Forms square tables and is readily soluble in water; fuses by heat, giving out vapour of hydrofluoric acid, and leaving a portion of neutral salt.

Procured by adding to hydrofluoric acid a quantity of potassa, insufficient for neutralizing it completely, and concentrating the solution. By slow evaporation crystals are obtained.—*Berzelius* and *Thenard*.

These compounds are probably in their dry states *Fluorides of Potassium*.

Nitrate of Potassa.—Atom. Num. 101·15*—Symb.* (5O+N)+(O+Po.)

SYN. *Saltpetre. Nitre.*

PROPERTIES. A colourless salt, crystallizing readily in six-sided prisms, the primitive form of which is a right rhombic prism; [*Levy, in Brande's Jour.* xv. 284] taste saline, accompanied with an impression of coolness; it requires for solution seven parts of water at 60° F. and its own weight of boiling water; it contains no water of crystallization, but its crystals are never quite free from water lodged mechanically within them; at 616° F. it undergoes the igneous fusion, and like all the nitrates, is decomposed by a red heat; it is also rapidly decomposed by sulphur, charcoal and phosphorus.

It is rapidly decomposed by charcoal, sulphur, &c.—This may be shown, by mixing two parts of powdered nitre with one of powdered charcoal, and setting fire to the mixture in an iron vessel under a chimney. The gaseous product of this combustion, which may be collected by a proper apparatus, is carbonic acid and nitrogen gas. Part of the carbonic acid also remains attached to the residuary alkali, and may be obtained from it by adding a stronger acid. This residue was termed by the old chemists, *Clyssus of Nitre:* if excess of charcoal be used, the results are carbonic oxide and acid, nitrogen and subcarbonate of potassa, formerly called *nitrum fixum* and *white flux.*

When phosphorus is thrown upon nitre and inflamed, a vivid combination ensues, and a phosphate of potassa is formed. Sulphur sprinkled upon hot nitre burns and produces a mixture of sulphate and sulphite of potassa, formerly employed in medicine under the name of *Glaser's polychrest salt.* Most of the metals, also, when in filings or powder, detonate and burn when thrown on red hot nitre.

A mixture of three parts of powdered nitre, two of carbonate of potassa and one part of sulphur, dried and accurately mixed together,

forms the *Fulminating Powder*, which explodes with a loud noise when laid on an iron plate heated below redness.

Gunpowder, consists of a very intimate mixture of nitre, sulphur and charcoal. The proportions vary. The following are those usually employed.

	Common Gunpowder.	Shooting Powder.	Shooting Powder.	Miners' Powder.
Saltpetre,	75.0	78	76	65
Charcoal,	12.5	12	15	15
Sulphur,	12.5	10	9	20

The latter contains the smallest quantity of saltpetre, as it requires less *quickness* or *strength*. The ingredients are *perfectly* mixed, moistened, beaten into a cake which is afterwards broken up, granulated, dried, and, for the finest powder, polished by attrition. The violence of the explosion of gunpowder depends upon the sudden production of gaseous matter, resulting from the action of the combustibles upon the nitre. Carbonic oxide, carbonic acid, nitrogen and sulphurous acid, are the principal gaseous results, and the solid residue consists of subcarbonate and sulphate of potassa, sulphuret of potassium and charcoal.—*Nicholson's Journal*, iv.

PREPARATION. This salt is generated spontaneously in the soil, and crystallizes upon its surface, in several parts of the world, and especially in the East-Indies, whence the greater part of the nitre used in Britain is derived. It is also found abundantly in several caverns in the western parts of the United States. [*Cleaveland's Mineralogy.*] In France and Germany, it is prepared artificially from a mixture of common mould or porous calcareous earth with animal and vegetable remains containing nitrogen. When a heap of these materials, preserved moist and in a shaded situation, is moderately exposed to the air, nitric acid is gradually generated, and unites with the potassa, lime and magnesia, which are commonly present with the mixture. On dissolving these salts in water, and precipitating the two earths by carbonate of potassa, a solution is formed, which yields crystals of nitre by evaporation. The nitric acid is probably generated under these circumstances by the nitrogen of the organic matters combining during putrefaction with the oxygen of the atmosphere, a change which must be attributed to the affinity of oxygen for nitrogen, aided by that of nitric acid for alkaline bases.— *Turner.*

USES. The greatest consumption of this salt is in the manufacture of gunpowder. It is also employed in the formation of nitric acid, and in chemistry, as an oxidizing agent. In the East Indies it is used for the preparation of cooling mixtures;—an ounce of powdered nitre dissolved in five ounces of water reduces its temperature fifteen degrees. It possesses powerful antiseptic properties, and is, therefore, much employed in the preservation of meat and animal matters in general.

ACTION ON THE ANIMAL ECONOMY. This salt is often mistaken for saline laxatives, especially for the sulphate of soda, and has thus been the source of fatal accidents. Cases of this kind are related by Dr. Christison in his *Treatise on Poisons.*

REFERENCES. *For a description of the mode of preparing this salt, see Thenard, Traité de Chim. Thomson on the effect of red heat upon Nitrate of Potassa, First Prin.* i. 107. *On the preparation of Gunpowder, Nicholson's Jour.* xxiii. 277. *Dr. Ure on the composition of Gunpowder, Journ. of the Roy. Inst.* Oct. 1830. *Longchamp on Nitrification, Phil. Mag. and Ann.* i. 172. *The article Gunpowder in the Supplement to the Enculopædia Britannica, by Dr. M'Culloch. Cutbush's Pyrotechny. Watson's Chemical Essays. Dumas, Traité de Chim.*

Hyposulphite of Potassa.—This salt is best formed by decomposing hydrosulphuret of potassa by sulphurous acid. The salt has a taste at first not unlike that of nitre, succeeded by bitterness, and it is deliquescent when carefully dried ; it takes fire on raising the heat, and burns like tinder, but with a feeble blue flame ; it dissolves chloride of silver, even when dilute, with great readiness.—*Henry's Chem.* i. 570.

Sulphite of Potassa.—A salt, occurring in rhomboidal plates of a white colour, and a bitter and sulphurous taste, very soluble, and which by exposure to air is converted into a sulphate. It is prepared by passing sulphurous acid into a solution of potassa and evaporating out of contact of air.

Hyposulphate of Potassa.—A salt crystallizing in cylindrical prisms terminated by a plane perpendicular to their axis. Little, however, is known concerning it.—*Ann. Phil.* xiv. 335. *Brande's Jour.* xv. 285.

Sulphate of Potassa.—*Atom. Num.* 87·15—*Symb.* $(3O+S)+(O+Po.)$

SYN. *Sal de duobus.*

PROPERTIES. White ; slightly bitter ; crystallizes in short six-sided prisms, terminated by six-sided pyramids ; it is destitute of water of crystallization and suffers no change by exposure to air ; decrepitates when heated, and enters into fusion at a red heat ; soluble in 16 parts of cold, and five of boiling water ; is decomposed at high temperatures by charcoal, and converted into sulphuret of potassium.

PREPARATION AND NATIVE STATE. This salt is found native, but not abundantly, being principally in combination with the acetate and hydrochlorate of potassa, in woody plants. It is artificially prepared by saturating carbonate of potassa with sulphuric acid ; and it is procured abundantly as a product of the operation for preparing nitric acid.

Bisulphate of Potassa.—Has a sour taste, and a powerful action upon vegetable blues ; one part is soluble in two of water, at 60° F. and in less than an equal weight at 212° F. ; insoluble in alcohol.

This salt may be easily obtained by dissolving in hot water the mass which remains in the retort after distilling nitric acid from equal weights of sulphuric acid and nitre ; or by digesting one proportion of the neutral sulphate with water containing about 50 parts of concentrated sulphuric acid, and evaporating the solution.— *Thomson, Ann. of Phil.* xxvi. 439.

Ammonia Sulphate of Potassa.—A triple salt, crystallizing in bril-

liant plates, of a bitter taste. Formed by adding ammonia to bisulphate of potassa.—*Thomson, First Prin.* ii. 417.

Hypophosphite of Potassa.—A very deliquescent salt, soluble in water and in alcohol, nearly in all proportions. It is formed by the direct combination of its constituents.—*Rose, Ann. de Ch. et de Ph. July,* 1828.

Phosphite of Potassa.—A neutral salt, not crystallizable, deliquescent, and very soluble in water, but not in alcohol. When heated, a yellow residue is left, which, with acids, gives out a little phosphuretted hydrogen.

Phosphate of Potassa.—This salt has little taste ; by the action of heat it undergoes igneous fusion ; mixed with 20 or 30 times its bulk of lime water, it preserves all its transparency.

It may be obtained by neutralizing a solution of carbonate of potassa with phosphoric acid, concentrating the solution and setting it aside for some days to crystallize.— *Thomson's Frst. Prin.* ii. 256.

Biphosphate of Potassa.—This salt has been very little examined ; it is formed by dissolving the phosphate in phosphoric acid, and evaporating till crystals are obtained, which are prismatic and very soluble.

Berzelius describes two other phosphates.— *Traité de Chim.* iii. 402.

Carbonate of Potassa.—*Atom. Num.* 69·15—*Symb.* $(2O+C)+(O+Po.)$

SYN. *Subcarbonate of Potash. Salt of Tartar.*

PROPERTIES. Taste strongly alkaline ; is slightly caustic, and communicates a green to the blue colour of the violet ; dissolves in less than an equal weight of water at 60° F. ; deliquesces rapidly on exposure to the air, forming a dense solution formerly called *oil of Tartar per deliquium ;* it crystallizes with much difficulty from its solution ; insoluble in pure alcohol ; fuses at a full red heat without decomposition.

PREPARATION. This salt is procured in an impure form from the potash and pearlash of commerce ; but for chemical purposes it should be prepared from cream of tartar, the bitartrate of potassa. On heating this salt to redness the tartaric acid is decomposed, and a pure carbonate of potassa mixed with charcoal remains. The carbonate is then dissolved in water, and after filtration, is evaporated to dryness in a capsule of silver or platinum. It may also be obtained by exposing the bicarbonate to a moderate heat, and dissolving the resulting salt in water ; the solution is then filtered to separate the silicic acid, evaporated to dryness, and kept in well stopped bottles. The carbonate prepared in this way is preferred by Berzelius in chemical analysis.

Commercial Potash and Pearlash.—If any vegetable growing in a soil not impregnated with sea-salt be burned, its ashes will be found alkaline from the presence of carbonate of potassa. By lixiviating the ashes thus obtained, with hot or cold water, the alkaline part is dissolved out, and this solution, when boiled to dryness, leaves behind a dark brown saline mass, consisting of carbonate of potassa with variable proportions of other salts and a minute quantity of vegetable inflammable matter. In this state it is known in commerce by the name

of *Potash*. Calcination at a moderate heat, burns off the colouring particles and the salt becomes of a spongy texture and beautiful bluish white tinge, and is then called *Pearlash*.

In this process hot water dissolves the alkali more rapidly and completely than cold, and is therefore to be preferred in the manufacture, and advantage is also gained by making use of small leach tubs. If quick lime be mixed with the ashes, previous to lixiviation, the alkali is rendered more caustic, and as some of the other salts of potash are decomposed by it, the value of the resulting mass will be increased.— But the addition of common salt or of any *soluble matter*, to the ashes, previous to lixiviation, or of any substance to the lixivium when undergoing the process of evaporation, impairs the quality of the potash, and can only be resorted to through ignorance or for fraudulent purposes.

Potash and Pearlash being so largely employed in the arts, it is frequently of consequence to ascertain the value of different samples; that is, to determine the quantity of real carbonate of potash contained in a given weight of impure carbonate. The purity of pearlash may in general be judged of by its easy solubility in water, two parts of which should entirely dissolve one part of the salt; the residue, if any, consists of impurities. But the purity of a given specimen may be more correctly determined by ascertaining its power of saturating an acid. Dilute sulphuric acid may be employed for this purpose. The amount of pure alkali which this test acid will saturate having been determined by previous experiments, it is next to be ascertained how much of this acid is required to saturate a given weight of impure potash, and from this the proportional amount of pure carbonate may be easily ascertained by calculation. Thus if eight ounces of this test acid, neutralizes one ounce of pure carbonate of potassa, and eight ounces of the same acid require for their neutralization two ounces of common potash, the latter contains one ounce of impurities. For a description of a convenient apparatus for ascertaining the purity of commercial potash, and soda, see *Faraday's Chemical Manipulation ; and also the Appendix to this work*.

The following table will exhibit the ingredients of several specimens of potash. The analyses were made by myself under the direction of a committee of the Legislature of New-York, in 1832 and 3, and were confined to such specimens as were met with in our market.—*See Assembly Journals*, 1832-3.

	Insoluble matter.	Sulphate of Potassa.	Chlorides of Potassium and Sodium.	Carbonic Acid and Hydrate of Potassa.	Total.
1	11.6	7.5	7.3	73.6	100
2	00.5	6.3	15.	78.2	100
3	2.4	12.2	10.8	74.6	100
4	1.6	11.5	10.	76.9	100
5	11.4	4.4	9.2	75.	100
6	7.6	10.4	32.8	49.2	100
7	1.7	12.5	6.9	78.9	100
8	2.5	10.2	11.1	76.2	100

Of these specimens, No. 1 & 7, were manufactured according to the common method. No. 2, 3, 4, 5, & 8, were made according to a method recently introduced of mixing lime with the ashes,—employing hot instead of cold water in the lixiviation, and using small leach tubs. No. 6. was the result of a mistaken idea which was maintained by some manufacturers, that the addition of large quantities of salt and lime to the lye would not only increase the amount of potash, but improve its quality.

REFERENCES. *Vauquelin's Experiments on various kinds of Potash, &c., Ann. de Chim.* xl. 273, *or Repertory of Arts,* 1st ser. xvi. 258, (*an important paper.*) *On obtaining Potash from various substances— Chaptal's Chem.* ii. 78. *John on the origin of Potash, in vegetables, Edin. Phil. Jour.* ii. 394. *A paper on commercial potash and soda by M. Descroizilles, Senr., Tilloch's Phil. Mag.* xxviii.

Bicarbonate of Potassa.—Atom. Num. 100·15—*Symb.* 2(2O+C)+(O+ Po)+1 aq.

PROPERTIES. Crystallizes in eight-sided prisms; is milder than the carbonate, but is alkaline both to the taste and to test paper ; does not deliquesce on exposure to the air ; it requires four times its weight of water, at 60° F. for solution, and is much more soluble at 212° F. but it parts with some of its acid at that temperature, and at a low red heat it is converted into the carbonate.

PREPARATION. This salt is made by transmitting a current of carbonic acid gas through a solution of the carbonate of potassa. By slow evaporation the salt is obtained in the crystalline form.

Sesquicarbonate of Potassa, seems to have been obtained accidentally in a single instance. Its constitution is stated by Dr. Thomson to be 1½ at. carbonic acid +1 potassa +6 water.—*First Prin.* ii. 255.

Sub-borate of Potassa.—This salt is little known. It may be formed by the direct combination of liquid hydrate of potassa with boracic acid. — *Thenard.*

Selenites of Potassa.—Selenious acid is capable of uniting with potassa in three different proportions, and of composing either a selenite, bi-selenite or quadri-selenite.—*Berzelius, Ann. de Ch. et de Phys.* ix. 257. *and Traité de Chim.* iii. 428.

TESTS OF THE SALTS OF POTASSA. 1. A concentrated solution of *Tartaric Acid,* added in excess to a concentrated solution of potassa or any of its soluble salts, immediately produces a crystalline precipitate of bitartrate of potassa. When the solution is dilute, the precipitate appears only after some time. 2. The spirituous solution of *Chloride of Platinum,* produces a yellow precipitate of chloride of potassium and platinum. If the salt which is to be tested for potassa, be soluble in alcohol, it is best to mix a spirituous solution of the salt with the spirituous solution of chloride of platinum.—*See Prof. H. Rose's Manual of Analytical Chemistry, for particulars concerning the employment of the above tests and several others of inferior delicacy.*

SECTION II.

SODIUM.

Atom. Num. 23·3.—*Symb.* So.—*Sp. gr.* 0·972.

Discovered by Sir. H. Davy, in 1807, and particularly examined by him, and by Gay Lussac and Thenard.—*Recherches Phys. Chim.*

PROPERTIES. Solid at ordinary temperatures; white, opaque, and when examined under a thin film of naphtha, has the lustre and general appearance of silver; is so soft that it may be formed into leaves by the pressure of the fingers, and possesses the property of *welding*; fuses at 200° F. and rises in vapour at a full red heat; it soon tarnishes on exposure to the air, though less rapidly than potassium; when thrown upon water, swims upon its surface, occasions a violent effervescence, and a hissing noise, but no light is visible; the action is stronger with hot water, and a few scintillations appear, but still there is no flame; in each case, soda is generated, owing to which the water acquires an alkaline reaction, and hydrogen gas is disengaged.

Sodium decomposes water.—When sodium is thrown upon pure water it rapidly decomposes the water, but does not take fire like potassium. This Serullas ascribes to its great mobility compared with that of potassium. And he says that if sodium be placed in contact with a little water, thickened by gum, it is then arrested, and enough of heat is speedily generated to set the sodium on fire. [*Ann. de Chim. et de Phys.* xl. 329.] According to Professor Ducatel, sodium inflames with cold water when in contact with charcoal, and the product is soda and sodiuretted hydrogen. [*Silliman's Jour.* xxv. 90.] Sodium burns with a yellowish flame, while that of potassium is reddish. It has also been observed that when sodium is pushed altogether under water, the disengagement of hydrogen gas is then so sudden and abundant as to cause a detonation.

PREPARATION. Sodium was first obtained by the action of the Voltaic battery upon soda; but it may be procured in much larger quantity by chemical processes, precisely similar to those described when treating of potassium.

SODIUM AND OXYGEN.

Chemists are acquainted with two compounds of sodium and oxygen, viz: the *protoxide* or *soda*, and the *peroxide*. Berzelius, however, describes a third, which he calls the *sub-oxide*; but it is probable that this is a mere mixture of the metal with soda.

Protoxide of Sodium, or Soda.—*Atom. Num.* 31·3—*Symb.* O+So.

PROPERTIES. Grayish-white; very caustic; difficult of fusion; specifically heavier than sodium; changes vegetable blues to green; when exposed to the air it becomes covered with an efflorescent crust of carbonate of soda.

PREPARATION. Soda is obtained by burning sodium in dry atmospheric air. It is also formed when sodium is oxidized by water.

Hydrate of Soda.—Atom. Num. 40·3—*Symb.* (O+So.)+(O+H.)

With water, soda forms a solid hydrate, easily fusible by heat ; very caustic, soluble in water and alcohol, and has powerful alkaline properties. It is prepared from solution of pure soda, exactly in the same manner as the corresponding compound of potassa.

Mr. Dalton has constructed a table showing the proportion of real soda, free from water, in solutions of different specific gravities.—[See *Henry's Chem.* i. 580.]

Peroxide of Sodium.—Atom. Num. 70·6—*Symb.* 3O+2So.

- This compound may be formed by burning the metal in an excess of oxygen gas. It is of a deep orange colour, very fusible, and a non-conductor of electricity. When acted on by water, its excess of oxygen escapes, and it becomes soda. It deflagrates with most combustibles.—*Gay Lussac* and *Thenard.*

SODIUM AND CHLORINE.

Chloride of Sodium.—Atom. Num. 58·75—*Symb.* Cl+So.

PROPERTIES. A crystalline solid, occurring in regular cubes, or by hasty evaporation, in hollow quadrangular pyramids, which, when the salt is pure, are but little changed by exposure to the air ; it dissolves in twice and a half its weight of water at 60° F., and is but little more soluble in hot water ; when heated, gradually fuses, and forms, when cold, a solid mass ; if suddenly heated, it decrepitates ; is not decomposed by ignition in con act with inflammable substances, except potassium ; is decomposed by carbonate of potassa, sulphuric and nitric acids, and when dissolved in water, is converted into *Muriate of Soda.*

PREPARATION AND NATIVE STATE. This compound may be formed directly by burning sodium in chlorine, or by heating it in muriatic acid gas. It is deposited in crystals, when a solution of muriate of soda is evaporated ; for this salt, like muriate of potassa, exists only while in solution In this state it is found abundantly as a natural product in sea water, and in the various brine springs, from which the crystalline compound is obtained by evaporation. Chloride of sodium is known likewise as a natural product under the name of rock or mineral salt.

Among the most valuable of the brine or salt springs in the United States, are those of Onondaga County, N. Y. The manufacture of salt from these springs commenced about the year 1789, but the quantity manufactured has greatly increased within the last ten years. In 1800 it amounted to 42,754 bushels ; in 1814, to 295,215 bushels ; in 1823, to 606,463 bushels; in 1833, to 1,838,646, and in 1835, to 2,222,694.

According to an analysis, which I made of the brine obtained at Salina, in 1837, it contains nearly one-seventh of its weight of pure and dry chloride of sodium. 1000 grains of this brine gave 146·50 grains of dry saline residuum, viz :—

Carbonate of lime,	-	-	-	-	0·17
Sulphate of lime,	-	-	-	-	4·12
Chloride of calcium,	-	-	-	-	1·04
Chloride of magnesium,	-	-	-	0·51
Chloride of sodium,	-	-	-	-	140·02
Oxide of iron, with a minute portion of					
silica and carbonate of lime,	-	-		0·04
Carbonic acid, holding in solution car-					
bonate of lime and oxide of iron,	-		0·94
Water, with a trace of organic matter					
and bromine,	-	-	-	-	853.41
					1000·00

The results of my analyses of the different varieties of salt manufactured in the County of Onondaga, are as follows.

Kinds of Salt.	Carbonates of Lime and Magnesia.	Sulphate of Lime.	Chlorides of Calcium and Magnesium.	Pure Chloride of Sodium.	Total.
Salt made by solar evaporation, at Geddes,	1.00	6.50	trace	992.50	1000
Salt made by solar evaporation, at Syracuse,		7.00	2.00	991.00	1000
By evaporation with artificial heat,		9.00	0.50	988.50	1000
Table salt prepared at Salina,	0.20	6.61	1.46	991.73	1000
Salt made by boiling in kettles, Salina,	0.40	20.09	3.26	976.25	1000.

In the specimens of salt analyzed by Dr. Henry, the proportion of chloride of sodium in 1000 parts of the salt varied from 937 to 988.

Uses. The uses of chloride of sodium are well known· Besides its employment in seasoning food, and in preserving meat from putrefaction, a property which when pure it possesses in a high degree, it is used for various purposes in the arts, especially in the formation of muriatic acid and chloride of lime.

Tests. Chloride of sodium is often contaminated with sulphate of lime, and the muriates of lime and magnesia. These earths may be precipitated as carbonates, by boiling a solution of salt for a few minutes with a slight excess of carbonate of soda, filtering the liquid and neutralizing with muriatic acid.

References. *Dr. Henry's Analysis of various kinds of British and foreign Salt, Repert. of Arts, 2d ser. xvii. Dr. J. Van Rensselaer's Essay on salt. Holland's Survey of Cheshire, Eng. Art. Cheshire, in the Edinburgh Encyclopedia. Dr. Hastings' Lecture on the Salt Springs of Worcestershire, (Eng.) New York Geological Reports for* 1838. *Dumas,*

Chimie appliquée aux Arts, contains an account of the various modes of manufacture, &c.

Iodide, Sulphuret and Phosphuret of Sodium.

The compounds of sodium with iodine, sulphur and phosphorus, are so analogous to those which potassium forms with the same elements, that a particular description of them is unnecessary.

On *nitrogen* gas sodium appears to have no action ; but when heated in ammoniacal gas, hydrogen is disengaged, and a *nitruret of sodium* is formed, which has an olive green colour, is fusible at a low heat, and according to the experiments of Gay Lussac and Thenard, is composed of 100 parts of sodium, and 19·821 nitrogen.— *Thenard, Traité de Chim.*

SODIUM AND THE METALS.

The history of these compounds is very similar to that of the alloys of potassium. Like those, when the union of sodium with the metals is direct, it is attended with the evolution of caloric. Some of the alloys of sodium also disengage light at the moment of their combination, viz. those of antimony, tellurium and arsenic.— *Thenard.*

SALTS OF SODA.

Chlorate of Soda.—Atom. Num. 106·75—*Symb.* (5O+Cl.)+(O+So.)

PROPERTIES. Soluble in three parts of cold water, and in rather less of hot, and is slightly deliquescent ; soluble also in alcohol ; crystallizes in cubes or in rhomboids approaching the cube in form ; produces a sensation of cold in the mouth, and a taste scarcely to be distinguished from that of muriate of soda ; agrees in other properties with the chlorate of potassa.

PREPARATION. This salt may be obtained by saturating chloric acid with soda, or by a process similar to that for preparing chlorate of potassa ; but it is difficult in this process to separate it from muriate of soda.— *Chenevix, Phil. Trans.* 1802. *Vauquelin, Ann. de Chim.* xcv. 96. *Ann. of Phil.* vii. 39.

Iodate of Soda.—Atom. Num. 197·3—*Symb.* (5O+I) +(O+So.)

PROPERTIES. Crystals small and prismatic : decomposable by heat, and is converted into oxygen and iodide of sodium ; not altered by exposure to air ; detonates feebly with sulphur by percussion.

PREPARATION. This salt is formed by dissolving iodine in solution of soda ; a white compound forms, which is the iodate with a portion of *Hydriodate of Soda ;* the latter may be removed by alcohol.

Hydrofluates of Soda.—Two hydrofluates of soda are known similar in constitution to those of potassa. They may be formed by similar processes.

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Nitrate of Soda.—Atom. Num. 85·3—*Symb.* $(5O+N)+(O+So.)$

SYN.   *Cubic Nitre,* of the older chemists.

PROPERTIES.   This salt crystallizes in rhombs, soluble in three parts of water at 60° F.,and in less than its weight at 212°; has a cool sharp flavour, and is somewhat deliquescent.

PEPARATION AND NATIVE STATE.   This salt has been found native in Peru. It may be formed by saturating carbonate of soda with nitric acid, or by distilling common salt with three-fourths of its weight of nitric acid. When the former process is adopted, the solution must be evaporated, till a pellicle appears on its surface, and it is then allowed to cool.

USES.   The only use of nitrate of soda is in the preparation of fire works. A powder prepared with six parts of this salt, one of sulphur and one of carbon, burns with a fine orange-yellow flame, but with much more rapidity than a like powder containing nitre.

Hyposulphite of Soda.—Deliquescent, and of an intensely bitter and nauseous taste; when heated, first fuses, then dries into a white mass, and at length takes fire and burns with a bright yellow flame; insoluble in alcohol, and has the property of rapidly dissolving the chloride of silver, when newly precipitated.

This salt may be prepared in the same way as the analogous salt of potassa. When the solution is evaporated to a syrupy consistency it crystallizes in silky tufts, radiating from a centre, and rendering the liquid solid.

Sulphite of Soda.—Crystallizes in white transparent four-sided prisms,with two broad sides and two narrow ones, terminated by dihedral summits; has a cool sulphurous taste; is soluble in four parts of cold, or less than its weight of boiling, water; effloresces upon exposure to the air, and is converted into a sulphate.

Sulphate of Soda.—Atom. Num. 161·7—*Symb.* $(3O+S)+(O+So)$
$$+10 \text{ aq.}$$

SYN.   *Glauber's Salt. Sal Mirabile.*
Discovered by Glauber, whose name it still bears.

PROPERTIES.   Taste bitter, cooling and saline; crystallizes in four and six-sided prismatic crystals, but its primary form is an octahedron; effloresces rapidly when exposed to the air; undergoes watery fusion when heated; at 32° F. 100 parts of water dissolve twelve parts of the crystals, 48 parts at 64·5°, 100 parts at 77°, 270 at 89·5°, and 322 at 91·5°. On increasing the heat beyond this point, a portion of the salt is deposited, being less soluble than at 91·5°.—*Gay Lussac.*

PREPARATION AND NATIVE STATE.   This salt is occasionally met with on the surface of the earth, and is frequently contained in mineral springs. It may be made by the direct action of sulphuric acid on carbonate of soda; and it is produced in large quantity as a residue in the processes for forming muriatic acid and chlorine.

The principal use of sulphate of soda is in pharmacy; but it is sometimes decomposed for the purpose of obtaining soda, by igniting

it with chalk and charcoal, or with iron and charcoal.—*See Aikin's Dictionary, Art. Muriate of Soda.*

Octohydrated Sulphate of Soda.—This salt occurs in the form of white four-sided prisms, and contains, according to Mr. Faraday, eight atoms of water instead of ten. [*Brande's Jour.* xix. 152.] It is formed by crystallizing in a supersaturated solution of sulphate of soda, made at a high temperature and set aside for some days, in a well corked phial. I obtained a portion of it some years since, in a bottle of solution of sulphate of soda, which had been prepared for the purpose of exhibiting the effect of the admission of air in determining crystallization, and upon analysis I found it to be a sulphate of soda, but in my specimens, the proportions of water did not exceed seven atoms.

Anhydrous Sulphate of Soda.—An opaque salt, whose primary form is a rhombic octahedron, and specific gravity is 2·462. It is formed by evaporating a solution of common sulphate of soda saturated at 91·5° ; at a higher temperature. And also by keeping a saturated solution of the common sulphate, in a temperature of 120° in a stove.— *Thomson's Inorg. Chem.* ii. 445. *Ann. of Phil.* xxviii. 403.

Bisulphate of Soda.—This salt may be formed by adding sulphuric acid to a hot solution of sulphate of soda. Large rhomboidal crystals are formed, which are soluble in twice their weight of water at 60° F., effloresce by exposure to air, and when heated, lose their excess of acid. —*Crell's Annals*, 1796.

Hypophosphite and Phosphite of Soda.—The phosphite of soda has not been examined. Hypophosphite of soda is very soluble in water and alcohol. Little else is known respecting it.—*Ann. de Chim. et de Phys.* ii. 142.

Phosphate of Soda.—Atom. Num. 179·5—*Symb.* (2½O+P)+(O+So)+ 12¼ aq.

Syn. *Sal Perlatum.*
Properties. Taste saline and not strong ; crystallizes in oblique prisms, which effloresce on exposure to the air, and require four parts of cold, and two of boiling water, for solution ; when heated it fuses and boils up, and having lost its water of crystallization, runs into a clear glass, which becomes opaque on cooling.

Preparation. This salt is usually obtained for pharmaceutical purposes, by saturating the impure phosphoric acid, obtained from calcined bones by sulphuric acid, with carbonate of soda ; the liquor is filtered, evaporated and set aside to crystallize.— *Thomson's First Prin.* ii. 270.

Pyro-phosphate of Soda.—This name has been given, by Mr. Clark of Glasgow, to phosphate of soda which has been subjected to a red heat. By this treatment, not only its water is expelled, but the salt appears to undergo some change of constitution, for its solution gives with nitrate of silver, not a yellow precipitate like that of the common phosphate, but a white one ; and when wholly decomposed by the salt of silver, the remaining solution is neutral, not acid, as when the common phosphate has been decomposed. Yet no gaseous or other product can be collected, except water. The crystallized phosphate

was found to contain, to each proportion, 25 proportions of water, [thus differing from Dr. Thomson] of which 24 were separated by a sand heat, and one by a red heat. The salt had then acquired the new properties which have been just described; and from its solution in water, crystals were obtained, obviously different in form from those of common phosphate of soda, and containing only 10 proportions of water.

These facts, if correctly observed, can only be explained by supposing a new arrangement of the elements of the phosphate, occasioned by the high temperature to which it has been exposed.—*Henry's Chem.* i. 593. *Brewster's Edin. Jour.* vii. 299.

Biphosphate of Soda.—Taste acid and saline; reddens vegetable blues, and is usually crystallized in four-sided prisms, terminated by four-sided pyramids.

This salt is prepared by adding phosphoric acid to a solution of the neutral phosphate of soda, until the solution ceases to precipitate muriate of baryta. Being very soluble in water, the solution must be concentrated, in order that it may crystallize; and it requires a long time, and a considerable quantity of the solution, to obtain large crystals.— *Thomson's First Prin.* ii. 272.

Phosphate of Soda and Ammonia.—*Atom. Num.* 209·7 ?—*Symb.* $2(2\frac{1}{2}O+P)+(O+So)+(N+3H)+10$ aq.

PROPERTIES. Primary form a right rhombic prism; taste saline and cooling; quite soluble in water; when heated, parts with its water of crystallization, and if the heat is raised to redness, the ammonia is likewise disengaged, leaving biphosphate of soda, which melts into a transparent glass, dissolves in water, and reddens vegetable blues.

PREPARATION. This salt exists in human urine. It is prepared artificially by dissolving one proportion of muriate of ammonia and two of phosphate of soda in a small quantity of boiling water. As the liquid cools, prismatic crystals of the double phosphate are deposited, while muriate of soda remains in solution.

This salt has long been known under the name of *fusible and microcosmic salt.* It is sometimes employed by mineralogists as a flux in experiments made by the blow-pipe.—*Fourcroy, Ann. de Chim.* vii. 183.

Phosphate of Soda and Potassa.—This salt is obtained, according to Mitscherlich, by adding carbonate of soda to a solution of biphosphate of potassa, until effervesence ceases. Upon evaporation the double salt crystallizes.—*Berzelius,* iii. 463.

Carbonate of Soda.—*Atom. Num.* 143·3—*Symb.* $(2O+C)+(O+So)+10$ aq.

SYN. *Subcarbonate of Soda of the Pharmacopœia.*

PROPERTIES. Crystallizes in octahedrons, with a rhombic base, the acute angles of which are generally truncated; the crystals effloresce on exposure to the air, and, when heated, dissolve in their water of crystallization; by continued heat are rendered anhydrous without loss of carbonic acid; dissolve in about two parts of cold, and less than their weight of boiling water, and the solution has a strong alkaline taste and reaction.

PREPARATION. The carbonate of soda of commerce is obtained by lixiviating the ashes of sea-weeds. The best variety is known by the name of *barilla*, and is derived chiefly from the *salsola soda* and *salicornia herbacea*. A very inferior kind known by the name of *kelp*, is prepared from sea-weeds on the northern shores of Scotland. The purest barilla, however, though well fitted for making soap and glass, and for other purposes in the arts, always contains the sulphates and muriates of potassa and soda, and on this account is of little service to the chemist. A purer carbonate is prepared by heating a mixture of sulphate of soda, saw-dust and lime, in a reverbatory furnace. By the action of the carbonaceous matter, the sulphuric acid is decomposed—its sulphur partly uniting with lime and partly being dissipated in the form of sulphurous acid, while the carbonic acid, which is generated during the process, unites with soda. The carbonate of soda is then obtained by lixiviation and crystallization. It is, however, difficult to obtain this salt quite free from sulphuric acid.—[For other processes, see *Berzelius, Traité de Chim.* iii. 466.]

The quantity of real carbonate in the soda of commerce may be conveniently estimated by its neutralizing power, which may be ascertained in the mode described in the remarks upon potash.

REFERENCES. *Report on the different methods of extracting Soda from Sea Salt, by Lelievre, Pelletier, &c. Jour. de Phys. or Repert. of Arts,* 2d ser. x. 230. *Gay Lussac and Welter on the Assay of Samples of Soda and Barilla of commerce. Ibid.* xxxvii. 241. *On obtaining Soda from Kelp, Muriate and Sulphate of Soda, Chaptal's Chem.* ii. 107. *Parkes' Chem. Essays,* iii. 121. *Dumas, Chim. appl. aux Arts.*

Sesquicarbonate of Soda.—*Atom. Num.* 82·3—*Symb.* $1\frac{1}{2}(2O+C)+$
$(O+So)+2$ aq.

This salt is found native in Barbary, where it is known by the name of *Trona.* It constitutes hard masses, which do not deliquesce in the air ; and it is said to be employed in the north of Africa, where rain seldom falls, for building the walls of houses. It is manufactured in London for the use of the soda-water makers, and is sold in the state of a white powder. It does not appear to be susceptible of crystallization. *Thomson's First Prin.* ii. 267. *R. Phillips, in Brande's Jour.* vii. 294. *For a description of a Trona or Natron Lake, see Prof. Jameson's remarks on the geology of Africa, in the volume of Harpers' Family Library, entitled " Discovery and Adventure in Africa."*

Bicarbonate of Soda.—*Atom. Num.* 84·3—*Symb.* 2 $(2O+C)+(O+So.)$
$+1$ aq.

PROPERTIES. Taste milder than that of the carbonate ; requires 9 or 10 times its weight of water at 60° F. for solution, which when heated liberates a part of the carbonic acid ; affects colour tests in the same manner as the subcarbonate ; by exposure to a low red heat it is rendered anhydrous.

PREPARATION. This salt may be prepared by saturating a weak solution of carbonate of soda, by passing through it a stream of carbonic acid ; or by dissolving 14 parts of carbonate of ammonia in a solution of 100 parts of carbonate of soda, and evaporating at a gentle heat.—*Thomson's First Prin.* ii. 267.

The nature of this compound, sometimes called also the *Chloride of Soda*, does not appear to have been definitively settled. It has been investigated by Dr. Granville, Mr. Phillips and Mr Faraday.—[See *Brande's Jour. N. S.* i. 371, *and* ii. 84. *Phil. Mag. and Ann.* i. 376]

It is most probable that this substance consists merely of chlorine held in solution by the dissolved salt—and that it is not a definite compound of chlorine and soda, or of chlorine and the carbonate of soda.—*Sill. Jour.* xiv. 251.

PROPERTIES. This compound, prepared according to the directions of Labarraque, has a pale yellow colour and a slight odour of chlorine ; taste at first sharp, saline and scarcely at all alkaline, but it produces a persisting biting effect on the tongue ; it first reddens, then destroys the colour of turmeric paper ; when boiled it does not give out chlorine, nor is its bleaching power perceptibly impaired ; and if carefully evaporated, it yields a mass of damp crystals, which, when redissolved, bleach almost as powerfully as the original liquid ; when rapidly evaporated to dryness, the residue contains scarcely any chlorate of soda or chloride of sodium, but it has nevertheless lost more than half its bleaching power, and therefore chlorine must have been evolved during the evaporation. The solution deteriorates gradually by keeping, chloric acid and chloride of sodium being generated. When allowed to evaporate spontaneously, chlorine gas is gradually evolved, and crystals of carbonate of soda remain.— *Turner.*

PREPARATION. This compound is easily prepared by transmitting a current of chlorine gas into a cold and rather dilute solution of caustic soda, or of the carbonate of that alkali. It may also be formed easily and cheaply, and of uniform strength, by decomposing chloride of lime with carbonate of soda, as proposed by M. Payen.— [*Brande's Jour. N. S.* i. 236.] The formula of Labarraque is as follows : 2800 grains of crystallized carbonate of soda are dissolved in 1·28 pints of water, and through the solution, contained in a Woulfe's apparatus, is transmitted the chlorine, evolved from a mixture of 967 grains of sea salt and 750 grains of peroxide of manganese, when acted on by 967 grains of sulphuric acid, diluted with 750 grains of water, the gas being passed through pure water to remove any accompanying muriatic acid.

USES. This compound may be employed for bleaching, and for all purposes to which chlorine gas or its solution was formerly applied. It is now much used in removing the offensive odour arising from drains, sewers, or all kinds of animal matter in a state of putrefaction. Bodies disinterred for the purpose of judicial inquiry, or parts of the body advanced in putrefaction, may, by its means, be rendered fit for examination ; and it is employed in surgical practice for destroying the fetor of malignant ulcers. Clothes worn by persons during pestilential diseases are disinfected by being washed with this compound. It is also used in fumigating the chambers of the sick ; for the disengagement of chlorine is so gradual, that it does not prove injurious or annoying to the patient. In all these instances, chlorine appears ac-

tually to decompose noxious exhalations by uniting with the elements of which they consist, and especially with hydrogen.

REFERENCES. *An Essay on the use of the Chlorurets of Oxide of Sodium and Lime as powerful disinfecting agents, &c. by Thomas Alcock. The Memoir of Labarraque, translated by Dr. Jacob Porter. See also facts stated by the author in a paper on these compounds, in the New-York Med. and Phys. Jour.* vii. 62.

Biborate of Soda.—Atom. Num. 151·3—*Symb.* 2(2O+B)+(O+So)
+8 aq.

SYN. *Subborate of Soda. Borax.*

PROPERTIES. Crystallizes in prisms with irregular sides; effloresces in the air; fuses when ignited, and then loses its water of crystallization, and is changed into a white powder, which, on increasing the heat, leaves a transparent mass, called *Glass of Borax*, a substance of great use in experiments with the blow-pipe; it changes the colour of syrup of violets to green, and was, therefore, considered as a subsalt.

PREPARATION AND NATIVE STATE. This salt occurs native in some of the lakes of Thibet and Persia, and is extracted from this source by evaporation. It is imported from India, in a crude state, under the name of *Tincal,* which after being purified, constitutes the *refined* borax of commerce.

A new variety of borax is obtained by dissolving, in boiling water, as much common borax as will give a solution of specific gravity 1·216. It forms octahedral crystals and contains only half the water of common borax.—*M. Payen, Brande's Jour. N. S.* iii. 483.

REFERENCES. *Thomson's First Prin.* ii. 270. *MM. Robiquet and Marchand's process for refining Borax, Ann. de Chim. et de Phys.* viii. 359. *Ann. of Phil.* xiii. 61. *Berzelius,* iii. 469.

Selenites and Selenate of Soda.—Berzelius describes three distinct selenites of soda, differing in the amount of acid which they contain. A *Selenate of Soda* is also recognized.—*Traité de Chim.* ii. 481.

TESTS OF THE SALTS OF SODA. 1. Upon adding sulphuric acid to soda a salt is obtained, which, by its taste and form, is easily recognized as Glauber's salt, or sulphate of soda. 2. All its salts are soluble in water, and are not precipitated by any re-agent. 3. On exposing its salts, by means of platinum wire, to the blow-pipe flame, they communicate to it a rich yellow colour. According to M. Harkort, of Freyberg, potash with nickel gives a blue glass before the blow-pipe, while soda gives a brown glass. This is said to be a very delicate test, provided the nickel is perfectly free from cobalt.—*Ure's Chem. Dict.*

SECTION III.

LITHIUM.

Atom. Num. 10—*Symb.* L.

Lithium is a white-coloured metal like sodium, which was first obtained from lithia by Sir H. Davy, by means of galvanism; but it was oxidized and reconverted into the alkali with such rapidity that it could not be collected.

LITHIUM AND OXYGEN.

Oxide of Lithium or Lithia.— *Atom. Num.* 18—*Symb.* O+L.

Discovered in 1818, by Arfwedson of Sweden, in the mineral called *Petalite*, and since that time also found in spodumene, lepidolite, and in several varieties of mica.

PROPERTIES. Soluble in water, and like the other alkalies has an acrid, caustic taste; changes vegetable blues to green; when heated in contact with platinum, it fuses and then acts on the metal; is distinguished from potassa and soda by its greater neutralizing power; when exposed to the air it absorbs carbonic acid and becomes opaque.

PREPARATION. A good process for preparing lithia is to mix powdered spodumene with twice its weight of pulverized fluor-spar, and with three or four of sulphuric acid; then to heat the mixture until the hydrofluoric acid with the silica is volatilized, and afterwards to separate the sulphate of lithia by solution. This salt may be decomposed by the acetate of baryta, and the acetate of lithia, thus obtained, is converted into a carbonate by exposure to a red heat. By the action of lime the carbonate may then be brought to the state of caustic hydrate. Berzelius describes other processes for obtaining this alkali.—*See Traité de Chim.* ii. 37.

REFERENCES. *Arfwedson, Ann. de Chim. et de Phys.* x. 82. *Berzelius on Lithia in Petalite, &c. Ann. of Phil.* xi. 291, 373, 447. *Gmelin's examination of the chemical properties of Lithia, Ann. of Phil.* xv. 341, 374.

LITHIUM AND CHLORINE.

Chloride of Lithium.—*Atom. Num.* 45·45—*Symb.* Cl+L.

This compound may be obtained by evaporating the muriate of lithia to dryness and fusing the residue. It is white and semi-transparent, extremely deliquescent, soluble in alcohol, is decomposed when strongly heated in the open air, when it parts with chlorine, absorbs oxygen and becomes highly alkaline; it is very difficultly crystallizable, and

tinges the flame of alcohol red. In all these respects it differs from the similar compounds of potassa and soda.

SALTS OF LITHIA.

These have not been very minutely examined, as the basis has not yet been very abundantly obtained.

Nitrate of Lithia is very soluble, and by ·evaporation crystallizes sometimes in regular rhomboids, sometimes in needles. It is extremely fusible; and at the instant when it has cooled, it attracts moisture from the air and becomes fluid.

Sulphate of Lithia crystallizes in small prisms, of a shining white colour. It is more fusible and soluble than sulphate of potassa, and has a saline and not a bitter taste.

Bisulphate of Lithia is produced by adding an excess of sulphuric acid to the sulphate. It is more fusible and less soluble in water than the sulphate.

Phosphate of Lithia is formed by adding phosphate of ammonia with excess of base to sulphate of lithia, when an insoluble phosphate falls down. By this property it may be separated from potassa and soda. There exists also a *biphosphate*.

REFERENCES. *On the Salts of Lithia, see Gmelin's paper in the Ann. of Phil.* xv., *and Berzelius, Traité de Chim.* iii. 488.

TESTS OF THE SALTS OF LITHIA. Lithia may be distinguished from potassa and soda by forming sparingly soluble salts with carbonic and phosphoric acids; by affording deliquescent salts with muriatic and nitric acids, which are freely soluble in alcohol. This alcoholic solution burns with a red flame; and all the salts of lithia, when heated on platinum wire before the blow-pipe, tinge the flame of a red colour. — *Berzelius on the Blow-pipe. Rose's Manual of Analytical Chemistry,* 54.

CLASS II.

METALS, WHICH, WHEN COMBINED WITH OXYGEN, FORM ALKA-LINE EARTHS.

SECTION IV.

BARIUM.

Atom. Num. 68·7—*Symb.* Ba.

The metallic basis of *baryta* was discovered by Sir H. Davy in 1808; but it has hitherto been obtained only in small quantities.

PROPERTIES. Colour dark gray, with a lustre inferior to that of cast iron ; specific gravity greater than water ; it attracts oxygen with avidity from the air, and is converted into baryta; effervesces strongly, from the escape of hydrogen when thrown into water, a solution of baryta being produced.

PREPARATION. This metal was obtained by Sir H. Davy, by a process suggested by Berzelius and Pontin. It consists in forming carbonate of baryta into a paste with water, and placing a globule of mercury into a little hollow made in its surface. The paste was laid upon a platinum tray which communicated with the positive pole of a galvanic battery of 100 double plates, while the negative wire was brought into contact with the mercury. The baryta was decomposed, and its barium entered into combination with mercury. This amalgam was then heated in a vessel free from air, by which means the mercury was expelled, and barium obtained in a pure form.—*Turner.* See also, *Berzelius, Traité de Chim.* ii. 346, *for a notice of another process.*

BARIUM AND OXYGEN.

Two compounds of barium and oxygen are at present known.

Protoxide of Barium.—Atom. Num. 76·7—*Symb.* O+Ba.

Discovered by Scheele in 1774, and called *Barytes* or *Baryta*, from the great density of its compounds.

PROPERTIES. A gray powder, the specific gravity of which is about 4 ; it requires a high temperature for fusion ; taste sharp and alkaline ; converts vegetable blue colours to green, and neutralizes the strongest acids ; has a strong affinity for water, and when mixed with that liquid it slakes in the same manner as quick lime, but with the evolution of a more intense heat, which, according to Dobereiner, sometimes

amounts to luminousness—the result being a white bulky hydrate, fusible at a red heat, and which bears the highest temperature of a smith's forge without parting with its water ; evolves light when acted on by concentrated sulphuric acid.

REFERENCES. *Ann. of Phil.* xviii. 77. *Ann. de Chim. et de Phys.* xxxvii. 223, *or Repert. of Pat. Invent.* vii. 94.

Hydrate of Baryta.—This hydrate is soluble in twice its weight of boiling water, and in twenty parts of water at the temperature of 60° F. A saturated solution of baryta in boiling water deposits, in cooling, transparent flattened prismatic crystals, which are composed, according to Mr. R. Phillips, of one atom of baryta and ten atoms of water.— *Lond. and Edin. Phil. Mag.* vii. 52.

The *Aqueous solution of Baryta* is an excellent test of the presence of carbonic acid in the atmosphere, or in other gaseous mixtures. The carbonic acid unites with the baryta, and a white insoluble precipitate, carbonate of baryta, subsides.

PREPARATION. Baryta may be prepared as above suggested, by exposing barium to the air. It may also be obtained by decomposing nitrate of baryta at a red heat ; or, as was ascertained by Dr. Hope, by exposing carbonate of baryta, contained in a black lead crucible, to an intense white heat ; a process which succeeds much better, when the carbonate is intimately mixed with charcoal.

Peroxide of Barium.—Atom. Num. 84·7—*Symb.* 2O+Ba.

A grayish white substance, employed by Thenard in the preparation of peroxide of hydrogen, (page 122.) It may be formed by conducting dry oxygen gas over pure baryta at a low red heat. An easier process, recommended by Wöhler and Liebig, is to heat caustic baryta in a platinum crucible, by means of a spirit lamp, until it is nearly red hot, and then to throw in, by small quantities at a time, chlorate of potash : incandescence takes place, and the protoxide becomes peroxide of barium. When the mass is cold, the chloride of potassium is dissolved out by solution in cold water ; the peroxide becomes a hydrate during this operation, and remains in the state of a white powder. It may be dried by exposure to the air, without heat. It appears to contain six atoms of water.

REFERENCES. *Ann. de Chim. et de Phys.* xxxv. 108. *Thenard, Traité de Chim.* ii. 328. *Edin. Jour. of Science,* ii. 180. *Webster's Brande.*

BARIUM AND CHLORINE.

Chloride of Barium.—Atom. Num. 104·15—*Symb.* Cl+Ba.

PROPERTIES. Taste pungent and acrid ; requires five times its weight of water at 60° for solution ; unaltered by exposure to the air ; decomposed by sulphuric acid and the alkaline carbonates ; when dissolved in water, is supposed to be changed into *Muriate of Baryta,* which may be obtained from the solution by evaporation in the form of tables or eight-sided pyramids, applied base to base. These crystals,

according to Dr. Thomson, consist of one proportion of muriate of baryta and one of water.

PREPARATION. The chloride is generated when chlorine gas is conducted over baryta at a red heat, and oxygen gas is disengaged. It may also be formed by heating to redness the crystallized muriate of baryta. This salt is best prepared by dissolving either the artificial or native carbonate, or the sulphuret, in dilute muriatic acid; and afterwards evaporating and crystallizing. In this form it is employed as a test for the presence of sulphuric acid.

REFERENCES. *The processes for the preparation of Muriate of Baryta by La Grange, &c. Ann. de Chim., or Repert. of Arts, 2d ser. iv. 439. viii. 139. Medical and Chemical History of, New-England, Med. Jour. iii. 23. On the poisonous properties of this and other compounds of Baryta, see Christison on Poisons.*

BARIUM AND BROMINE.

Bromide of Barium.

This has been obtained by boiling proto-bromide of iron with moist carbonate of baryta in excess, evaporating the filtered solution, and heating the residue to redness. The product crystallizes by careful evaporation in white rhombic prisms, which have a bitter taste, are slightly deliquescent, and are soluble in water and alcohol.

BARIUM AND IODINE.

Iodide of Barium.

This compound may be formed by acting upon baryta by hydriodic acid, and evaporating the solution. It may also be formed by heating baryta in hydriodic gas; water and iodide of barium are the results. When thrown into water, it is converted into *Hydriodate of Baryta.*

BARIUM AND SULPHUR.

Sulphuret of Barium.

The proto-sulphuret of barium may be prepared from sulphate of baryta by the action of charcoal or hydrogen gas at a high temperature. It dissolves readily in hot water, forming the hydrosulphuret of baryta. By means of this solution, all the chief salts of baryta may be procured. Thus, by adding an alkaline carbonate, carbonate of baryta is precipitated; and when muriatic acid is added, sulphuretted hydrogen is evolved, and muriate of baryta produced. A solution of pure baryta may also be obtained from the hydrosulphuret, by boiling it with peroxide of copper, until the filtered solution no longer gives a dark precipitate with acetate of lead. The crystallized hydrate of baryta is easily procured by means of this solution.— *Turner.*

BARIUM AND PHOSPHORUS.

Phosphuret of Barium.

This compound decomposes water and gives out phosphuretted hydrogen like the preceding phosphurets. It may be formed by heating to redness anhydrous caustic baryta in a glass matrass, furnished with a long neck, and then throwing pieces of phosphorus into it.—*Berzelius,* ii. 358.

SALTS OF BARYTA.

Chlorate of Baryta.—Atom. Num. 152·15—*Symb.* (5O+Cl)+(O+Ba.)

PROPERTIES. Crystallizes in the form of four-sided prisms; taste pungent and austere; requires for solution about four times its weight of water at 50° F., and its solution when pure is not precipitated either by nitrate of silver or muriatic acid; by a red heat loses 39 per cent., and the remainder is alkaline.

PREPARATION. The readiest mode of preparing this salt is by the process of Mr. Wheeler. On digesting, for a few minutes, a concentrated solution of chlorate of potassa with a slight excess of silicated hydrofluoric acid, the alkali is precipitated in the form of an insoluble double hydrofluate of silica and potassa, while chloric acid remains in solution. The liquid, after filtration, is neutralized by carbonate of baryta, which likewise throws down the excess of hydrofluoric acid and silica. The silicated hydrofluoric acid employed in the process, is made by conducting fluosilicic acid gas into water.

This salt is of interest, as being the compound employed in the formation of chloric acid.

Iodate of Baryta.—Atom. Num. 242·7—*Symb.* (5O+I)+(O+Ba.)

An extremely insoluble salt, formed by adding iodine to solution of baryta, from which the iodate precipitates in the state of a white powder, and may be edulcorated by washing with distilled water. When strongly heated, oxygen and iodine are evolved from it, and baryta remains.

Nitrate of Baryta.—Atom. Num. 130·7—*Symb.* (5O+N)+(O+Ba.)

PROPERTIES. Crystallizes in transparent octahedrons; not altered by exposure to air; soluble in 12 times its weight of water, at 60° F. and 3 or 4 parts of boiling water; insoluble in alchol; in a red heat its acid is decomposed, and the earth remains pure.

This salt is easily prepared by dissolving the natural or artificial carbonate of baryta in nitric acid, diluted with eight or ten times its weight of water, or by decomposing the sulphuret of barium by nitric acid and evaporating the solution. It is employed as a test, and when mixed with equal parts of charcoal is used for making green fire.

Hyposulphite of Baryta.—A white shining scaly powder, slightly soluble in water, and obtained by adding muriate of baryta to a concentrated solution of hyposulphite of lime.

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Sulphite of Baryta.—An insoluble compound, formed by mixing sulphite of potassa and muriate of baryta.

Sulphate of Baryta.—*Atom. Num.* 116·7—*Symb.* (3O+S)+(O+Ba.)

PROPERTIES. This salt, sometimes called *Heavy Spar*, is white, insipid, absolutely insoluble in water, sulphuric acid forming a sudden and sensible precipitation in water, which contains 1-20,000 of baryta, or even of any barytic salt : it dissolves sensibly in concentrated sulphuric acid, but does not dissolve in the weak acid ; at a very elevated temperature it is fused.—[*Thenard.*] When heated to redness it acquires the property of phosphorescence, and is sometimes called *Bologna Phosphorus.*—[*For details of the process, see Henry's Chem.* i. 630.] It is decomposed by being subjected to high heat in contact with charcoal.

NATIVE STATE AND PREPARATION. Sulphate of baryta, or heavy spar, is found abundantly in nature. It is met with in the mines of Cumberland and Westmoreland, and in Transylvania, Hungary, Saxony, and Hanover. It also occurs in various parts of the United States, especially in company with galena, in Missouri and Illinois.

This salt may be obtained artificially by turning a solution of sulphate of potassa or of soda into a solution of the nitrate or muriate of baryta. In this state it is used as a pigment under the name of *Permanent White.*

As the sulphate of baryta is a common and abundant native product, it is made use of for obtaining pure baryta and the other salts. For this purpose several processes have been contrived. The most convenient one consists in mixing the sulphate finely powdered, in the proportion of six parts, with one part of powdered charcoal, and exposing these to a red heat, for half an hour, in an earthen crucible. This converts the sulphate into sulphuret of barium, which is to be dissolved in hot water, and the solution filtered. To this solution we may add dilute nitric acid, if we wish to obtain nitrate of baryta, or muriatic acid, if the muriate is required. The solution is then to be evaporated and crystallized.

Hypophosphite of Baryta.—A very soluble salt, crystallizable with difficulty.—*Dulong, Ann. de Chim. et de Phys.* ii. 142.

Phosphite of baryta.—Obtained by Berzelius, by adding muriate of baryta to phosphite of ammonia ; a crust of phosphite of baryta was formed in 24 hours.

Phosphate of Baryta.—Insoluble in water, and formed by mixing solutions of muriate of baryta and phosphate of soda.

Biphosphate of Baryta.—A crystalline salt, with an acid taste and reaction ; obtained by Berzelius by dissolving phosphate of baryta in phosphoric acid, and evaporating the clear solution.

Berzelius describes three other phosphates of baryta.—*Ann. of Phil.* xv. 277.

Carbonate of Baryta.—*Atom. Num.* 98·7—*Symb.* (2O+C)+(O+Ba.)

Exceedingly insoluble in distilled water, requiring 4300 times its weight of water at 60° F. and 2300 of boiling water for solution ; but

when recently precipitated it is dissolved much more freely by a solution of carbonic acid ; is highly poisonous. It occurs abundantly in the lead mines of the north of England, where it was discovered by Dr. Withering, and has hence received the name of *Witherite*. It may be prepared by way of double decomposition, by mixing a soluble salt of baryta with any of the alkaline carbonates or bicarbonates.—*See Parkes' Chem. Essays*, ii. 186.

Seleniates of Baryta.— Selenic acid is capable of uniting with baryta in two proportions. The neutral salt, which is insoluble, consists of 100 acid +137 base ; the *biseleniate*, which crystallizes in round transparent grains and is soluble in water, is composed of 100 acid +68 base. —*Henry*, i. 631.

Tests of the salts of baryta.—1. The soluble salts of baryta are precipitated as a white carbonate of baryta, by alkaline carbonates, and as sulphate of baryta, which is insoluble, both in acid and alkaline solutions, by sulphuric acid or any soluble sulphate. 2. By forming with muriatic acid a salt, which crystallizes readily by evaporation in the form of four, six or eight-sided tables, is insoluble in alcohol, and does not undergo any change on exposure to air.—*See Rose's Manual of Analytical Chemistry*.

SECTION V.

STRONTIUM.

Atom. Num. 43·8—*Symb.* Sr.

Strontium may be obtained in minute quantities, by the same process as barium, substituting the carbonate of strontia, which is a native product, for the carbonate of baryta. It resembles barium, is fusible with difficulty, and not volatile. It decomposes water with the evolution of hydrogen, and is converted into an oxide by exposure to the air.

STRONTIUM AND OXYGEN.

Protoxide of Strontium or Strontia.—*Atom. Num.* 51·8—*Symb.* O+Sr.

Properties. A gray substance, with a pungent, acrid taste, and when powdered in a mortar, the dust that rises irritates the lungs and nostrils ; resembles baryta in appearance, in fusibility and in possessing distinct alkaline properties ; it may be slaked with water, which causes an intense heat.

The *Hydrate of Strontia* fuses readily at a red heat, but the water cannot be driven off by the strongest heat of a blast furnace. It is very soluble in boiling water, which deposits it in crystals upon being allowed to cool undisturbed, and which are composed, according to Mr. R. Phillips, of one atom of strontia and ten atoms of water.

The *Solution of Strontia* has a caustic taste and an alkaline re-action. Like the solution of baryta, it is a delicate test of the presence of car-

bonic acid in air and other gaseous mixtures, forming with it the insoluble carbonate of strontia.

PREPARATION. Strontia can be obtained by exposing the metal to air, or by subjecting the nitrate or carbonate of strontia to a strong red heat.

Peroxide of Strontium.—*Atom. Num.* 59·8—*Symb.* $2O+Sr$.

A white substance, of a brilliant satiny lustre, inodorous and almost tasteless. It is formed in the same manner as the corresponding preparation of barium, and also by pouring an aqueous solution of strontia into the deutoxide of hydrogen.—*For details and preparation, see Thenard, Traité de Chim.*

STRONTIUM AND CHLORINE.

Chloride of Strontium.—*Atom. Num.* 79·25—*Symb.* $Cl+Sr$.

This compound is formed under precisely the same circumstances as the chloride of barium. It is soluble in water, and is then converted into a *Muriate of Strontia,* which crystallizes in long slender hexagonal prisms, which are soluble in two parts of water at 60°, and to almost any amount in boiling water. In a very moist atmosphere these crystals deliquiate. They dissolve in alcohol, and give to its flame a blood-red colour.

Iodide of Strontium may be obtained in the same manner as iodide of barium. Dissolved in water and carefully evaporated, it furnishes delicate prismatic crystals of *Hydriodate of Strontia,* which, when heated in close vessels, fuse and become iodide of strontium by loss of water.

Sulphuret of Strontium may be formed by fusing strontia and sulphur in a green glass tube; or by exposing the powdered sulphate to a red heat with charcoal. It dissolves in water with the same phenomena as the sulphuret of potassium, and its solution furnishes, by cautious evaporation, crystals of *Hydrosulphuret of Strontia.*

SALTS OF STRONTIA.

Chlorate of Strontia.—A deliquescent salt having an astringent taste, and detonating when thrown upon red hot coals with a beautiful purple light; formed by the direct action of chloric acid upon carbonate of strontia.— *Vauquelin.*

Iodate of Strontia.—A difficultly soluble compound, requiring some hundred parts of water for solution, and resolved by red heat into oxygen, iodine and strontia.

Nitrate of Strontia.—*Atom. Num.* 105·8—*Symb.* $(5O+N)+(O+Sr.)$

PROPERTIES. A salt crystallizing in octahedrons or irregular prisms; soluble in its own weight of water at 60° F., or in little more than half its weight of boiling water; is fused at a red heat and afterwards decomposed, giving out oxygen, nitrogen and gaseous nitrous acid, and leaving strontia in a porous mass. When the crystals are applied to the wick of a candle, or added to boiling alcohol, they give a blood-red colour to the flame.

PREPARATION. This salt may be obtained in the same manner as the nitrate of baryta. The compound called *red fire*, is prepared by mixing together 40 parts of dry nitrate of strontia, 15 of chlorate of potassa, 13 finely powdered sulphur, and 4 sulphuret of antimony.—*See Brande's Jour.* ix. 411, *and Cuthbush's Pyrotechny.*

Sulphate of Strontia.—*A tom. Num.* 91·8—*Symb.* (3O+S)+(O+Sr.)

PROPERTIES. White, tasteless, of a specific gravity of about 4; fusible at a high temperature; nearly insoluble, one part requiring nearly 4,000 of water for its solution, when heated with charcoal is decomposed, and sulphuret of strontium is formed.

NATIVE STATE AND PREPARATION. This salt is found native in considerable quantities. It is sometimes of a blue tint, and has hence been called *Celestine*. Sometimes it is colourless and transparent.—Its primitive form is a prism, with a rhomboidal base. Fine crystals are found on Strontian Island, in Lake Erie.

It may be artificially prepared in the same manner as the sulphate of baryta. It is sometimes used as a flux.—*Brande's Jour.* vii. 183.

Phosphate of Strontia.—A tasteless salt, insoluble in water, but soluble in an excess of phosphoric acid; fusible by the blow-pipe into a white enamel, and decomposable by sulphuric acid; by ignition with charcoal it furnishes *Phosphuret of Strontium.*

It is formed by mixing solutions of muriate of strontia and sulphate of soda.

Besides this salt, there is also a *Biphosphate*, consisting of two atoms of acid, one of base, and two of water.

Carbonate of Strontia.—Known in mineralogy by the name of *Strontianite.* It occurs native at Strontian in Argyleshire, and at Schoharie, in the state of New York; and may be prepared in the same manner as carbonate of baryta. It is very insoluble in pure water, but is dissolved by an excess of carbonic acid.

REFERENCES. *For further notices of the salts of Strontia, see an account of the Analysis of Stromeyer, in Brande's Jour.* iii. 215; *and in Ann. of Phil.* iv. 394; *and Thomson's First Prin.* ii. 285.

TESTS OF THE SALTS OF STRONTIA. The salts of strontia resemble those of baryta in being precipitated by sulphuric acid or the soluble sulphates. Strontia may be distinguished from baryta; 1. By its forming with muriatic acid a salt which crystallizes in the form of slender hexagonal prisms, deliquesces in a moist atmosphere, and is very soluble in pure alcohol. 2. The alcoholic solution when set on fire burns with a deep red flame; and the salts of strontia, when exposed to the blow-pipe flame on platinum wire, impart to it a red tinge. 3. The hydrofluosilicic acid precipitates barytic salts, but forms with strontia a salt very soluble in slight excess of the acid.*—*Berzelius.*

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* Mr. Andrews has given a very simple method of detecting the presence of baryta and strontia in lime. The whole is dissolved in nitric acid, evaporated to dryness, and the acid expelled by heating to redness in a platinum crucible. The caustic residue is boiled with water, when the whole of the

See also *Rose's Manual of Analytical Chemistry, and Henry's Chem.* ii. 581. *Andrews' in Phil. Mag. and Ann.* vii. 404.

SECTION VI.

CALCIUM.

Atom. Num. 20·5— *Symb.* Ca.

First obtained by Sir H. Davy, in 1808, by exposing lime to the action of a voltaic battery.

PROPERTIES. Calcium is a white metal having the lustre and colour of silver, and which, when exposed to air and gently heated, is oxidized and converted into lime. Its other properties are unknown. It is obtained by a process similar to that employed for procuring barium.

CALCIUM AND OXYGEN.

: *Protoxide of Calcium or Lime.*—*Atom. Num.* 28·5—*Symb.* O+Ca.

PROPERTIES. Colour light gray; taste acrid and caustic; it converts vegetable blues to green; specific gravity 2·3; very difficult of fusion, but remarkably promotes the fusion of other bodies, and is therefore used in several metallurgic processes as a cheap and powerful flux; it can only be fused when quite pure by the oxygen blow-pipe or by the voltaic flame, and then only in minute particles; when exposed to the air it becomes white by the absorption of water and a little carbonic acid.

Hydrate of Lime.—The combination of lime with water is attended with a great increase of temperature and the formation of a white bulky hydrate.—The process of *slaking* lime consists in forming this hydrate, and the hydrate itself is called *slaked lime*. It differs from the preceding hydrates, in parting with its water at a red heat,—and it possesses the singular property of being more soluble in cold water than in hot water.—*Dalton.*

Lime-Water is prepared by mixing hydrate of lime with water, agitating the mixture repeatedly, and then setting it aside in a well-stopped bottle until the undissolved parts shall have subsided. The substance called *milk* or *cream of lime*, is made by mixing hydrate of lime with a sufficient quantity of water to give it the liquid form; it is merely lime-water in which hydrate of lime is mechanically suspended.

Lime-water has a harsh acrid taste, and changes vegetable blues to green; it has a strong affinity for carbonic acid, and forms with it an

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baryta and strontia and only a little of the lime are dissolved. Sulphuric acid added to the solution shows if any of these two earths are present, while a boiling saturated solution of sulphate of strontia troubles it, if it contains baryta, but causes no precipitate if the earth be strontia.—*Johnston's Report on Chemistry.*

insoluble carbonate, hence lime-water should be carefully protected from the air—for the same reason also, it is rendered turbid by a solution of carbonic acid ; but on adding a large quantity of the acid, the transparency of the solution is completely restored, because carbonate of lime is soluble in excess of carbonic acid.

PREPARATION OF LIME. The ordinary process for obtaining lime, is to expose common lime-stone (carbonate of lime) to a strong heat in a kiln ; carbonic acid is expelled by the heat, and pure lime, called *quicklime*, remains. But if lime of great purity is required, it should be prepared by calcining, in a crucible for several hours, Carrara or Parian marble, or carbonate of lime which has been precipitated by carbonate of ammonia from the muriate, and perfectly edulcorated by abundance of distilled water.

REFERENCES. *Gay Lussac on the crystallization of Lime, Ann. de Chim. et de Phys.* i. 334, *or Ann. of Phil.* viii. 150. *R. Phillips, on the solution and crystallization of Lime, Ann. of Phil.* xvii. 107. *Dalton on the solubility of Lime in cold and hot water, Brande's Jour.* xi. 202. *Whytt on the various strength of different Lime-waters, Edin. Literary Essays,* i. 420. *For details concerning the manufacture of Lime, see Aikin's Dictionary ; and Dumas, Chim. Appl. aux Arts.*

Peroxide of Calcium.—Atom. Num. 36·5—*Symb.* 2O+Ca.

When oxygen gas is passed over ignited quick-lime it is absorbed, and a portion of peroxide of calcium is formed. A similar peroxide united with water, is formed also, according to Thenard, when lime is brought into contact with the deutoxide of hydrogen, discovered by that chemist.— *Traité de Chim.*

CALCIUM AND CHLORINE.

Chloride of Calcium.—Atom. Num. 55·95—*Symb.* Cl+Ca:

PROPERTIES. Taste bitter and acrid ; deliquesces rapidly upon exposure to the air ; is soluble in a very small quantity of water, and is then converted into *Muriate of Lime ;* soluble in alcohol ; when fused it acquires a phosphorescent property, as was first observed by Homberg, and hence called *Homberg's Phosphorus.*

PREPARATION. This compound may be prepared by heating lime in chlorine gas ; one volume of chlorine is absorbed, half a volume of oxygen is evolved, and a chloride of calcium is formed. It may also be formed by saturating muriatic acid with carbonate of lime, evaporating to dryness and fusing the residue. It is abundantly produced in the manufacture of carbonate of ammonia, from the decomposition of muriate of ammonia by lime, and hence has sometimes been called *Fixed Sal Ammoniac.*

USES. On account of the great affinity of this compound for water, it is much employed to deprive gases and other substances of their moisture. It is also used for forming frigorific mixtures with snow.
[See page 54.]

Chloride of Lime.

This compound, called also *Oxymuriate of Lime* or *Bleaching Powder*, is prepared by exposing thin strata of recently slaked lime in fine powder, to an atmosphere of chlorine. The gas is absorbed in large quantity, and, according to some chemists, combines directly with the lime. Mr. Dalton, M. Welter and Dr. Thomson, consider the bleaching powder a hydrated *subchloride* or *dichloride of lime*, containing one proportion of chlorine united to two proportions of lime; Berzelius supposes it to be a *Chlorite of Lime*, or lime in combination with what he denominates chlorous acid, the peroxide of chlorine of other chemists; while Dr. Ure maintains that the elements of this compound do not constitute a regular atomic combination,—an opinion which appears to be entitled to most credit.

PROPERTIES. A dry white powder, which smells faintly of chlorine, and has a strong taste; it dissolves partially in water, the solution possessing strong bleaching powers, and being gradually decomposed by exposure to the atmosphere; the dry powder is decomposed by heat, evolving first chlorine and afterwards pure oxygen gas.

TESTS. The most convenient process for estimating the value of this powder, is that of Welter's, which consists in ascertaining the power of the bleaching liquid to deprive a solution of indigo of known strength of its colour; and directions have been drawn up by Gay Lussac for enabling manufacturers to employ this method with accuracy. [*Ann. of Phil.* xxiv. 218.] For analytical purposes, the best method is to decompose chloride of lime, confined in a glass tube over mercury, by means of muriatic acid. Muriate of lime is generated, and the chlorine being set free, its quantity may easily be measured.

USES. This compound, first prepared by Mr. Tennant of Glasgow, is now extensively employed in the art of bleaching. It is also largely used as a disinfecting agent.

REFERENCES. *For Papers on the nature of this compound by Dalton, Welter, Thomson, and Ure, see Ann. of Phil.* i. 15. ii. 6. xiii. 182. xv. 401, *Ann. de Chim. et de Phys.* viii. *Brande's Jour.* xiii. 1 ; *also, Silliman's Jour.* xiv. 251. *Ure's Chem. Dictionary. Labarraque on the preparation of Chloride of Lime, Edin. New Phil. Jour.* i. 320. *Tennant's Patent for Bleaching with compounds of Chlorine and Lime, &c , Repert. of Arts,* 1st *ser.* ix. 303. *And for further details concerning the employment of this powder, see Parkes' Chemical Essays ; Cooper, in the Emporium of Arts,* iii. 158 ; *the Art. Bleaching, in the supplement to the Edin. Encyclopedia ; and Berthollet's Work on the same subject.*

CALCIUM AND IODINE.

Iodide of Calcium.—Atom. Num. 146·5—*Symb.* I+Ca.

A white fusible compound, obtained by evaporating to dryness the hydriodate of lime, and strongly heating the residue ; when dissolved in water it is again converted into *Hydriodate of Lime.*

CALCIUM AND FLUORINE.

Fluoride of Calcium.—Atom. Num. 39·18—*Symb.* F+Ca.

SYN. *Fluate of Lime. Fluor,* or *Derbyshire Spar.*
A natural product found in many parts of the world, and often worked into ornaments; when crystallized it most commonly occurs in cubes, but its primitive form is an octahedron; its specific gravity is 3·15; is tasteless and insoluble in water; emits a phosphorescent light when thrown upon an iron plate heated below redness; evolves hydrofluoric acid when acted upon by concentrated sulphuric acid, but is not decomposed by anhydrous sulphuric acid. [See page 128.]

CALCIUM AND SULPHUR.

Sulphuret of Calcium.—Atom. Num. 36·5—*Symb.* S+Ca.

This compound was formed by Berzelius by passing sulphuretted hydrogen gas over red hot lime, the oxygen of which united with the hydrogen to form water, while the sulphur united with the calcium.— Berthier formed it also by exposing anhydrous sulphate of lime to a strong heat in a charcoal crucible.
The phosphorescent substance called *Canton's Phosphorus,* which is made by exposing a mixture of calcined oyster-shells and sulphur to a red heat, is supposed to be a sulphuret of lime; but its real composition has not been determined.

CALCIUM AND PHOSPHORUS.

Phosphuret of Calcium.—Atom. Num. 36·2—*Symb.* P+Ca.

When the vapour of phosphorus is passed over fragments of red hot lime, a portion of phosphuret of calcium is formed, mixed with phosphate of lime and some uncombined phosphorus and lime. This substance was formerly regarded as a phosphuret of lime, but there is no doubt that a compound of phosphorus with the metallic base is formed. The evidence of this fact is that, when properly prepared, it decomposes water, and liberates phosphuretted hydrogen, which can only be ascribed to the action of calcium upon the water. [See page 170.]

SALTS OF LIME.

Chlorate of Lime, is a very soluble deliquescent salt of a sharp bitterish taste, soluble also in alcohol, and giving out oxygen gas when heated. It is most easily produced by dissolving carbonate of lime in chloric acid.

Iodate of Lime, is difficultly crystallizable in small quadrangular prisms, requiring for solution several hundred times its weight of water: when exposed to a strong heat it is decomposed, oxygen and iodine are given off, and the base remains.

Nitrate of Lime.—Atom. Num. 109·5—*Symb.* (5O+N)+(O+Ca.)
+3 aq.

PROPERTIES. Very bitter and deliquescent ; soluble in four parts of water at 60° F. ; difficult to procure in regular crystals, but when the solution is boiled down to the consistence of a syrup, and exposed in a cool place, long prismatic crystals are formed, resembling in their disposition, bundles of needles diverging from a common centre ; when calcined to a certain degree it acquires the property of emitting light in the dark, and was formerly known by the name of *Baldwin's Phosphorus ;* if a concentrated solution of potassa be added to a saturated solution of this salt, the whole becomes a solid mass, because the lime which is precipitated absorbs the water of the liquid. This phenomenon was called by the older chemists, the *chemical miracle. Thenard, Traité de Chim.*

NATIVE STATE AND PREPARATION. This salt is found mixed with nitrate of potassa, in caverns, &c. also in the cement of old buildings. It is prepared artificially by treating coarsely powdered carbonate of lime by dilute nitric acid.

Sulphite of Lime, is a white powder, soluble by excess of sulphurous acid and then crystallizing in six-sided prisms, terminated by long six-sided pyramids. It is formed by passing sulphurous acid into a mixture of lime and warm water.

There is also a *Hyposulphite of Lime* and a *Hydrosulphuret of Lime.* These compounds have been examined by Mr. Herschell.

Sulphate of Lime.—Atom. Num. 68·5—*Symb.* (3O+S)+(O+Ca)

PROPERTIES. Destitute of taste and smell ; difficultly soluble, requiring 500 times its weight of cold and 450 of hot water ; fusible by a moderate heat, and after calcination absorbs water, becomes hot and *sets* rapidly ; at a red heat parts with some of its acid ; [*Thomson*] is decomposed by the alkaline carbonates, a double exchange of principles ensuing ; is decomposed also by ignition with charcoal.

PREPARATION AND NATIVE STATE. This salt is easily formed by mixing a solution of muriate of lime with any soluble sulphate. It occurs abundantly as a natural production. The mineral called *Anhydrite* is an anhydrous sulphate of lime ; and all the varieties of *Gypsum* are composed of the same salt, united with water.

USES. When the hydrous salt is deprived of its water by a low red heat, it forms *Plaster of Paris.* This possesses the property of becoming hard when made into a thin paste with water, owing to the chemical combination of the anhydrous sulphate with that liquid. Hence it is used in *stucco* work, and in taking casts, busts, &c. Prof. Emmet has ascertained that raw gypsum, finely pulverized, is capable of undergoing immediate and perfect solidification, when mixed with certain solutions of the alkali potassa. Among those that answer best, may be enumerated caustic potassa, carbonate and bicarbonate, sulphate and bisulphate, silicate and double tartrate or Rochelle salt. [*Silliman's Jour.* xxiii. 209.] The common gypsum is largely employed in agriculture.

REFERENCES. *Thomson's First Prin.* ii. 293. *Thenard*, iii. 176. *Gay Lussac on the setting of Plaster, Franklin Jour. N. S.* vii. 68.

Sulphate of Soda and Lime.—Occurs native in the form of transparent crystals, and is known by mineralogists under the name of *Glauberite.*

Phosphate of Lime.— Atom. Num. 64·2—*Symb.* $(2\frac{1}{2}O+P)+(O+Ca.)$

PROPERTIES. An insipid white powder; insoluble in water, but soluble in diluted nitric, muriatic and acetic acids, and again precipitable, unaltered, from those acids by caustic ammonia; at a high temperature it fuses into an opake white enamel.

PREPARATION AND NATIVE STATE. This salt is the principal ingredient in animal bones, of which it constitutes about 86 per cent. It may be obtained by dissolving bones, which have been well calcined and then pulverized, in dilute muriatic acid, adding ammonia to the solution and washing and drying the precipitate; or by mixing solutions of phosphate of soda and muriate of lime.

Biphosphate of Lime.—Atom. Num. 99·9—*Symb.* $2 (2\frac{1}{2}O+P)+ (O+Ca.)$

PROPERTIES. A white deliquescent uncrystallizable mass, which strongly reddens vegetable blues, and dissolves in water without decomposition; before the blow-pipe it melts into a transparent glass, insoluble in water.

It may be formed by digesting phosphate of lime with a quantity of phosphoric acid equivalent to that already engaged in the salt.

Triphosphate of Lime, occurs in hexagonal prisms in the mineral called *Apatite.*

Carbonate of Lime.—Atom. Num. 50·5—*Symb.* $(2O+C)+(O+Ca.)$

PROPERTIES. Very sparingly soluble in pure water, but is dissolved by water saturated with carbonic acid; it is decomposed by a strong red heat, and by almost all the acids, giving rise, in the latter case, to the phenomenon of *effervescence;* fusible at a heat of about 22° of Wedgewood's pyrometer, if the escape of the carbonic acid is prevented by strong pressure—[*Sir James Hall in Nicholson's Jour.* xiii. *and* xiv.] and by the sudden application of a violent heat, without additional compression—[*Bucholz, Nicholson's Jour.* xvii. 229;] is decomposed into its ultimate elements by being heated with phosphorus.— *Tennant, in Phil. Trans. for* 1791.

PREPARATION AND NATIVE STATE. Lime-water, when exposed to an atmosphere of carbonic acid becomes soon covered with a crust of carbonate of lime. This salt may also be obtained by adding hydrate of lime to any of the carbonates of the alkalies.

Carbonate of lime is a very abundant natural production, and occurs, under a great variety of forms; such as calcareous spar, Iceland spar, chalk, marble and common lime-stone.

Bicarbonate of Lime.—Exists only in solution: and in this state is

often found in mineral waters. If a current of carbonic acid is passed through lime-water, the solution becomes milky, and carbonate of lime is precipitated ; but if the current of gas be continued, the solution again becomes transparent ;—the bicarbonate, thus formed, being dissolved by the water.

Carbonate of Soda and Lime.—A mineral occurring at Merida, in South America, in transparent and colourless crystals. It was named *Gay-lussite* in honour of Gay Lussac. It consists of 1 atom carbonate of soda ; 1 atom carbonate of lime and 11 atoms of water.—*Berzelius, Traité de Chim.* iv. 78.

Carbonate of Baryta and Lime,—found native in Cumberland (Eng.) and known by the name of *Baryto-calcite.* It occurs in oblique rhombic prisms, translucent, having a yellowish brown tinge, and consists of 1 atom carbonate of baryta and 1 atom carbonate of lime.—*Ann. of Phil. N. S.* viii. 114.

TESTS OF THE SALTS OF LIME. The most delicate test of the presence of lime is oxalate of ammonia or potassa ; for, of all the salts of lime, the oxalate is the most insoluble in water. This, however, will not distinguish lime from baryta or strontia ; for this purpose the best characters are, that nitrate of lime yields prismatic crystals by evaporation, is very deliquescent and very soluble in pure alcohol.

The salts of lime, when heated before the blow-pipe, or when their alcoholic solutions are fired, communicate to the flame a dull brownish red colour.

SECTION VII.

MAGNESIUM.

Atom. Num. 12·7—*Symb.* Mg.

The existence of the metallic basis of magnesia was demonstrated by Sir H. Davy, but the metal was obtained by him in quantities too minute for determining its properties. M. Bussy, of Paris, has, however, procured this metal by the decomposition of the chloride, by a process similar to that employed by M. Wöhler, (see the next section.)

According to Bussy, magnesium is brilliant, silvery white, perfectly ductile and malleable, fusible at a moderate temperature, like zinc volatilized at a temperature a little higher than that of its melting point, and, like that metal, condenses in small globules ; it does not decompose water at common temperatures ; it oxidizes at a high temperature, and is slowly converted into magnesia, when in small masses, but when in filings, it burns with great splendour, throwing out sparks, like iron in oxygen.—*Phil. Mag. and Ann.* vii. 389.

MAGNESIUM AND OXYGEN.

Oxide of Magnesium or Magnesia.—*Atom. Num.* 20·7—*Symb.* O+Mg.

PROPERTIES. A white insipid friable powder, of an earthy appearance, slightly *greening* the blue of violets ; specific gravity 2·3 ; almost infusible and very sparingly soluble in water ; it absorbs carbonic

acid from the air at ordinary temperatures; has a weaker affinity than lime for water, for though it forms a *hydrate* when moistened, the combination is effected with hardly any disengagement of caloric, and the product is readily decomposed by a red heat.

There probably exist several different compounds of water and magnesia, but the *native hydrate* is the only one known with certainty.— This occurs at Hoboken, in New-Jersey, and on Staten Island, in New York.

NATIVE STATE AND PREPARATION. Magnesia is by no means a rare production of nature; for though very seldom found in a state approaching to purity, yet it enters largely into some rocks that compose extensive formations, such as serpentine, steatite, &c., and in combination with sulphuric and muriatic acids, it forms a large proportion of the ingredients of sea-water. Its principal use is in medicine.

Magnesia is artificially prepared by exposing carbonate of magnesia to a strong red heat, by which carbonic acid is expelled. This forms what is called in the shops, *Calcined Magnesia*, the purity of which can be tested by a small quantity of sulphuric acid; if effervescence ensues, we infer that carbonic acid is not entirely expelled. According to Mr. Donovan, during the ignition of magnesia a bright white light is emitted by the earth, apparently of the phosphoric kind; a phenomenon which also attends the ignition of some other earths.

Chloride of Magnesium may be obtained by passing chlorine over red hot magnesia; but an easier process, suggested by Liebig, is to mix equal weights of dry muriate of magnesia and sal-ammoniac, and project the mixture in successive portions into a platinum crucible kept at a red heat. When the ammoniacal salt is wholly expelled, the fused chloride of magnesium is left in a state of tranquil fusion, and on cooling becomes a transparent colourless mass which is highly deliquescent, and is very soluble in alcohol and water. It is by the action of potassium on this compound, that the metal magnesium is most conveniently obtained. When exposed to the air, the chloride of magnesium is converted into *muriate of magnesia*, which forms one of the ingredients of sea-water.

A compound, called *Chloride of Magnesia*, is prepared by passing chlorine gas into water in which magnesia is kept mechanically suspended, or by a mixture of solutions of chloride of lime and sulphate of magnesia. It has not yet been accurately investigated. It has been used with advantage in some of the processes of bleaching and calico-printing.—*Henry*, i. 368.

SALTS OF MAGNESIA.

Nitrate of Magnesia.—Atom. Num. 128·7—*Symb.* (5O+N)+(O+Mg) +6 aq.

PROPERTIES. Very bitter, deliquescent, and very soluble in water; crystallizes in small needles and sometimes in rhomboidal prisms; most commonly, however, it forms a shapeless mass; when exposed to the heat of ignition, it fuses, a few bubbles of oxygen gas first escape, and the nitric acid then passes undecomposed.

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This salt which also occurs in nature, may be artificially prepared by dissolving carbonate of magnesia in dilute nitric acid, and evaporating the solution.

Sulphate of Magnesia.—Atom. Num. 123·7— Symb. $(3O+S)+(O+Mg)$ $+7$ aq.

PROPERTIES. Taste saline, bitter, and naseous; it crystallizes readily in small quadrangular prisms, which effloresce slightly in a dry air, and is obtained also in larger crystals, which are irregular six-sided prisms terminated by six-sided summits; its primary form is a right rhombic prism, the angles of which are 90° 30′ and 89° 30′. (*Brooke*) ; the crystals are soluble in an equal weight of water at 60°, and in three-fourths of their weight of boiling water,—undergo the watery fusion when heated, and the anhydrous salt is deprived of a portion of its acid at a white heat.

NATIVE STATE AND PREPARATION. This sulphate, generally known by the name of *Epsom Salt*, is frequently contained in mineral springs. It may be made directly, by neutralizing dilute sulphuric acid with carbonate of magnesia ; but it is procured for the purpose of commerce by the action of dilute sulphuric acid on magnesian lime-stone, the native carbonate of lime and magnesia.

There are also a *Hyposulphite*, and a *Sulphite of Magnesia.*

REFERENCES. *Longchamp's experiments on Sulphate of Magnesia, Ann. de Chim. et de Phys.* xii. 255, *or Ann. of Phil.* xvi. 44. *Holland's account of the manufacture of Sulphate of Magnesia at Monte de la Gaurdia, near Genoa, Phil. Trans.* 1816 ; *Ann. of Phil.* viii. 61. *Mojon, on the same subject, Jour. de Phys. or Repert. of Arts,* 2d ser. v. 392.

Sulphate of Ammonia and Magnesia may be obtained by mixing a solution of sulphate of ammonia with solution of sulphate of magnesia ; in which case, one part only of the magnesia is thrown down, the remainder forming with the sulphate of ammonia this triple salt, which crystallizes in octahedrons.

By a similar process triple sulphates of soda and magnesia, and of potassa and magnesia, may be formed.— *Thomson's First Prin.* ii.

Phosphate of Magnesia.—A salt crystallizing in flat four-sided prisms, which effloresce in the air. It is formed by the direct union of its constituents, or by mixing solutions of sulphate of magnesia and phosphate of soda.— *Thomson's First Prin.* ii. 304.

Phosphate of Ammonia and Magnesia or Ammonio-phosphate of Magnesia.—This salt usually occurs in the form of a white insoluble powder ; but in certain varieties of urinary calculi, it is found lining cavities in a distinctly crystallized form, and is deposited in crystals on the sides of vessels in which urine has been long kept ; it is tasteless —scarcely soluble in water—readily soluble in dilute acids, and is decomposed by heat, leaving phosphate of magnesia only.

This salt may be prepared by mixing solutions of phosphate of ammonia and phosphate of magnesia, or any other soluble salt with a base of that earth. Dr. Wollaston availed himself of the formation of this triple salt, to separate magnesia from other earths. It consists,

according to Dr. Thomson, of one atom of phosphate of ammonia+ one atom phosphate of magnesia + four water.—*First Prin.* ii. 425.

Carbonate of Magnesia.—*Atom. Num.* 42·5—*Symb.* (2O+C)+ (O+Mg.)

A salt occurring native in great abundance in Hindostan, and also at Hoboken, New-Jersey, in veins in a serpentine rock, accompanying the native hydrate. Its colour is snow-white ; its specific gravity 2·73 ; it is rather harder than fluor spar, and it dissolves very slowly in acids, unless it be reduced to powder, and the action of acids promoted by heat.

The artificial carbonate of magnesia, *Magnesia Alba* of the shops, varies considerable in its composition. Berzelius has shown that the composition is regulated by the quantity of water employed, and by the temperature ; for the powder is obtained by precipitating the sulphate and muriate of magnesia, with an alkaline carbonate. He is of opinion that this is a compound of three atoms of carbonate of magnesia, with one atom of the quadro-hydrate of the same earth.— *Thomson's First Prin.* ii. 303.

This compound requires 2493 parts of cold, and 9000 of hot water for solution. It is so soluble in an excess of carbonic acid, that the sulphate of magnesia is not precipitated at all in the cold by the alkaline bicarbonates, or by the sesquicarbonate of ammonia. On allowing a solution of carbonate of magnesia in carbonic acid to stand in an open vessel, minute crystals are deposited, which consist of 42 parts or one proportion of the carbonate, and 27 parts or three proportions of water.

References. *Berzelius, in Ann. of Phil.* xii. 386. *Henry's Chem.* ii. 641.

Carbonate of Magnesia and Potassa is described by Berzelius, *Edin. Phil. Jour.* ii. 66.

Biborate of Magnesia.—This salt occurs in small irregular crystals, sparingly soluble in water, but soluble in acetic acid. It is found native in a mineral called *Boracite,* hitherto found only near Luneburg, in Germany. It may be prepared artificially by dissolving magnesia in boracic acid.—*Thomson's First Prin.* ii. 304.

Tests of the salts of magnesia. Most of the salts of magnesia are soluble, and when the solutions are neutral, white precipitates are produced upon the addition of pure ammonia and carbonate of potassa.— When the solutions are acid, they are distinguished from solutions of potassa, soda and ammonia salts, by producing a white precipitate with a solution of phosphate of soda, after having been supersaturated with ammonia. They are distinguished from solutions of lithia salts, by affording a precipitate with an excess of potassa, particularly when the mixture is boiled. From solutions of baryta and strontia, they are distinguished by affording no precipitate with diluted sulphuric acid; and from solutions of lime, by their relation towards oxalic acid.— *Rose's Manual of Analyt. Chem.*.

For further information concerning the separation of lime and magnesia, see *Phillips, in Brande's Jour.* vi. 316 ; *Cooper, same work,* vii. 392 ; *Daubeny, Edin. Phil. Jour.* vii. 108 ; *Brande's Manual ; Henry's Chem.* ii. 582.

CLASS III.

METALS, WHICH, WHEN COMBINED WITH OXYGEN, FORM EARTHS.

SECTION VIII.

ALUMINUM.

Atom. Num. 13·7—*Symb.* Al.

The existence of the metallic basis of alumina was first rendered probable by Sir H. Davy. But it is to Wohler that we are indebted for having first exhibited it in a metallic state, by a process suggested by Oersted.

PROPERTIES. This metal as prepared by Wohler, is a gray powder, of a tin white colour, especially when compressed in a mortar and rubbed with a burnisher; its aspect is decidedly metallic; it is infusible at the heat at which cast iron melts; it does not conduct electricity, but this is probably owing merely to its pulverulent form, which deprives other metals of that property, though they decidedly possess it in mass [*Henry*, i. 651]; heated to redness in the air, it takes fire, and burns with great brilliancy into white and tolerably hard alumina; when introduced red hot into oxygen gas it burns with a splendour which the eye can hardly support, and with so much heat that the resulting alumina is, in part at least, fused into yellow fragments, which are as hard as corundum, and not only scratch, but absolutely cut glass; it is scarcely acted on by water; is acted on by hot sulphuric acid, and by diluted sulphuric and muriatic acids, and soluble also in solutions of potassa and ammonia.

PREPARATION. The process for preparing this metal consists in mixing the chloride of aluminum with potassium, and heating the mixture in a small porcelain or platinum crucible, the cover of which is fixed to it by iron wire. Intense heat is developed during the action, the crucible though but gently heated externally becoming suddenly red hot. When the crucible is quite cold, it is put into a large glass of water in which the saline matter is dissolved, with slight disengagement of hydrogen gas, of an offensive odour; and a gray powder separates, which on close inspection, especially in sunshine, is found to consist solely of minute scales of metal. After being washed with cold water, it is pure aluminum.

REFERENCES. *Oersted, in Phil. Mag. and Ann.* ii. 391. *Wohler, in the same work,* iv. 147, *or Edin. Jour. of Science,* ix. 177.

ALUMINUM AND OXYGEN.

Oxide of Aluminum or Alumina.—Atom. Num. 25·7—*Symb.* 1½O+Al.

PROPERTIES. When pure, this substance has neither taste nor smell, and does not effect the colours of vegetables ; it is not soluble in water, but when moistened with that fluid forms a cohesive ductile mass; has a strong affinity for moisture, and after ignition greedily absorbs it from the atmosphere, to the amount of half its weight ; it is capable of combining both with the fixed alkalies and with acids, but is very sparingly taken up by the volatile alkali, and not at all by the alkaline carbonates ; it has a strong affinity for colouring matter, and is much used in the processes of dyeing and calico printing.

It shrinks in bulk when exposed to heat.—On this property is founded the *Pyrometer* of Mr. Wedgewood, which measures high degrees of heat, by the amount of contraction of regularly shaped pieces of China clay. This instrument, however, is not an accurate measure of heat, since the contraction of clay is influenced not merely by the degree of heat to which it is exposed, but by the mode of its application. *Henry,* i. 654.

NATIVE STATE AND PREPARATION. Alumina is most abundantly distributed in the mineral kingdom of nature. It is found nearly in a state of purity in the precious gems, the ruby and the sapphire; and is a constituent of the oldest rocks and the most recent alluvial deposition. The mineral called *Gibbsite,* is a native hydrate of alumina composed of one atom of water and one of alumina ; and the different kinds of clay, of which porcelain, pipes and bricks are made, consist of the hydrate of alumina, in various degrees of purity. It may be obtained free from the admixture of other earths, for chemical purposes, by precipitating a solution of alum in water, by ammonia or the carbonates of the fixed alkalies ; a white bulky hydrate of alumina is thus obtained, which when carefully washed and heated to whiteness, affords the pure anhydrous earths. An easier process, proposed by Gay Lussac, is to expose the sulphate of alumina and ammonia to a strong heat, so as to expel the ammonia and the sulphuric acid.—*Ann. de Chim. et de Phys.* v. 101.

M. Gaudin has recently announced the interesting fact that rubies may be artificially prepared. His process consisted in mixing some ammoniacal alum with from four to five thousandths of chromate of potash ; the whole being previously calcined, he gave it the form of a spherical cup upon the concave part of which he directed the flame of a powerful compound blow-pipe. In a few minutes the inner surface of this cup was covered with globules of a beautiful ruby red-colour, slightly translucent, and some of which exhibited the form and cleavage of the ruby. Upon analysis, these globules were found to be composed of 97 parts of alumina, two parts silica and lime and one oxide of chrome ; which composition is analogous to that of the ruby.—*Lond. and Edin. Phil. Mag.* xi. 563.

There are probably several different *Hydrates of Alumina.* See *Thomson's First Prin.* i. 315, *and Berzelius,* ii. 369.

ALUMINUM AND CHLORINE.

Chloride of Aluminum.—Atom. Num. 49·15—·*Symb.* Cl+Al.

PROPERTIES. Colour pale greenish-yellow, partially translucent and of a highly crystalline lamellated texture—somewhat like talc, but without regular crystals ; it fumes slightly when exposed to the air, emitting an odour of muriatic acid gas and deliquescing into a clear liquid ; when thrown into water is speedily dissolved with a hissing noise, and so much heat is evolved that the water, if in small quantity, is brought into a state of brisk ebullition, and the solution is common *Muriate of Alumina.*

PREPARATION. This chloride may be produced by the direct combination of its two ingredients ; but it may be more easily obtained by calcining pure alumina intimately mixed up with sugar and oil, and passing chlorine over the mixture at a red heat. The charcoal of the sugar and the oil abstract the oxygen of the alumina, and carbonic oxide is formed ; the aluminum at the same time unites with the chlorine.— *Wohler, Phil. Mag. and Ann.* iv. 147.

Sulphuret of Aluminum.—A vitrified semi-metallic mass which acquires an iron-black metallic lustre, when burnished. It is formed by dropping a piece of sulphur on aluminum, when strongly incandescent, so that it may be enveloped in an atmosphere of the vapour of sulphur —the union being affected with vivid emission of light.

Phosphuret of Aluminum.—A blackish gray pulverulent mass, which by friction acquires a dark gray metallic lustre, and in the air smells instantly of phosphuretted hydrogen. It is formed by heating aluminum to redness in contact with the vapour of phosphorus.

Seleniuret of Aluminum.—A black pulverulent substance assuming a dark metallic lustre when rubbed, and emitting in the air, a strong odour of seleniuretted hydrogen. It is formed with the disengagement of heat and light, by heating to redness, a mixture of selenium and aluminum.— *Wohler, in the paper above quoted.*

SALTS OF ALUMINA.

Nitrate of Alumina may be formed by dissolving fresh precipitated alumina in nitric acid. The solution, which is always acid, crystallizes in thin ductile plates. The crystals are extremely soluble, and are deliquescent. When dried by pressure between folds of blotting paper, Dr. Thomson finds them to consists of 1 atom of nitric acid, 2 atoms of base and 10 of water. He calls it a *Dinitrate.* By a stronger heat, it loses a portion of acid, and is then converted into what he calls a *Trisnitrate.—First Prin.* ii. 312.

Sulphate of Alumina.—White, very styptic, reddens vegetable blues, it usually occurs in the form of a semi-transparent mass, but is with difficulty crystallized. It may be obtained by digesting sulphuric acid over hydrate of alumina.

There is also a *Subsulphate of Alumina,* known to mineralogists by the name of *Aluminite,* a fine white mineral, found in Sussex, in Eng-

land, and in other places; it is called by Dr. Thomson, *Trisulphate of Alumina.—First Prin.* ii. 311.

Sulphate of Alumina and Potassa.

SYN. *Alum. Potash—Sulphate of Alumina*—Thomson.

PROPERTIES. Taste sweetish and astringent; crystallizes in regular octahedrons; dissolves in five parts of water, at 69° F. and in little more than its own weight of boiling water; reddens the blue of litmus; exposed to heat the crystals swell up and become a dry mass, called *Burnt Alum*, [*Alumen Ustum* of the Pharmacopeia]; it loses a part of its acid at a red heat. According to Dr. Thomson the crystalline salt consists of 3 atoms sulphate of alumina +1 atom sulphate of potassa +25 atoms water =509·25. But according to Berzelius the composition may be thus stated, viz : 2 atoms sesqui-sulphate of alumina +1 atom sulphate of potassa +24 atoms water =474·55.

PREPARATION. This salt is usually prepared by roasting and lixiviating certain clays containing pyrites; to the leys a certain quantity of potassa is added, and the triple salt is obtained by crystallization. It is extensively used in the arts, more especially in dyeing and calico printing, in consequence of the attraction which alumina has for the colouring matter. It also forms, when ignited with charcoal, a spontaneously inflammable compound, which has long been known under the name of *Homberg's Pyrophorus.*

REFERENCES. *A memoir on Alum, by Dr. T. R. Beck, in the Transactions of the Soc. of Useful Arts of the State of New-York,* iv. part ii. 50, *containing a detailed account of its history, manufacture, uses, &c. The art. Alum, in the Supplement to the Encyclopedia Britannica, by Dr. Thomson. Dr. Coxe, on Homberzh's Pyrophorus, Ann. of Phil.* i. 68. *Hare on Pyrophorus, Silliman's Jour.* x. 366. *Gay Lussac on the same subject, Ann. de Chim. et de Phys.* xxxvii. 415, *or Brande's Jour. N. S.* iv. 207.

Sulphate of alumina forms, with sulphate of ammonia and with sulphate of soda, double salts, which are very analogous to common alum. —*Riffault, Ann. de Chim. et de Phys.* ix. 106. *Ann. of Phil.* xvii. 72. *Beatson, Brande's Jour.* viii. 386. *Thomson's First Prin.* ii.

TESTS OF THE SALTS. Alumina may be recognized as follows: 1. It is separated from acids as a hydrate, by all the alkaline carbonates, and by pure ammonia. 2. It is precipitated by pure potassa or soda, but the precipitate is completely redissolved by an excess of the alkali.

SECTION IX.

GLUCINUM.

Atom. Num. 17·7—*Symb.* G.

The metallic basis of glucina was first obtained, in a separate state, by Wohler.

PROPERTIES. A dark gray powder, resembling in all respects, a metal precipitated in the pulverulent form; under the burnisher, it as-

sûmes a dull metallic lustre; its fusing point is very high; it undergoes no change, either in air or when exposed to boiling water; when heated to redness on platinum foil, it takes fire, and burns with great brilliancy, and glucina is regenerated; in oxygen it burns with extraordinary brilliancy, and yet the glucina formed gives no indications of fusion; it burns also in chlorine, and in the vapours of bromine and iodine.

PREPARATION. The process of Wohler consists in subjecting chloride of glucinum to heat, in contact with potassium, in a platinum crucible.— *Wohler, Ann. de Chim: et de Phys.* xxxix. 77, *or Phil. Mag. and Ann.* v. 392.

GLUCINUM AND OXYGEN.

Oxide of Glucinum or Glucina.—Atom. Num. 25·7—*Symb.* O+G.

Discovered by Vauquelin, in 1798.

PROPERTIES. A white powder, which has neither taste nor odour, and is quite insoluble in water; specific gravity 3; it does not affect vegetable colours; forms, with acids, salts having a sweetish taste, a circumstance which distinguishes glucina from the other earths, and from which its name is derived; it is soluble in liquid potassa or soda, but not in a solution of ammonia; it is, on the other hand, completely taken up by carbonate of ammonia, and is precipitated from it by boiling, a property which distinguishes it from other earths with which it might be confounded.

NATIVE STATE AND PREPARATION. This earth has been ascertained to exist only in three rare minerals, viz. the beryl, the emerald and the euclase. It is commonly prepared from beryl.—*See Berzelius, Traité de Chim.* ii. 376 ; *also Turner's and Henry's Chem.*

Berzelius describes a *Sulphuret* and a *Phosphuret of Glucinum*, obtained by heating the metal in the vapour of sulphur or phosphorus.

SECTION X.

YTTRIUM.

Atom. Num. 32·2—*Symb.* Y.

The base of yttria has been extracted by Wohler, in a manner similar to that employed for separating glucinum; but there appears to be much more difficulty in obtaining yttrium pure. The heat developed by the action of potassium on chloride of yttrium is very intense. The result, after separating what is soluble by water, is a metal of an iron black colour, in scaly particles of a perfectly metallic lustre. The fragments appeared to be brittle, not like alumina, ductile. At common temperatures, yttrium is not combustible in air, nor oxidable by water. Heated to redness it burns in the air, and its combustion in oxygen is one of the most brilliant that can be exhibited. Its remaining properties closely resemble those of glucinum.

YTTRIUM AND OXYGEN.

Oxide of Yttrium or Yttria.—Atom. Num. 40·2. *Symb.* O+Y.

Discovered in 1794, by Professor Gadolin, in a very rare mineral from Ytterby, in Sweden, from whence it derives its name, and subsequently examined by Klaproth and Vauquelin.

PROPERTIES. A perfectly white and very ponderous substance, having a specific gravity of 4·8 ; devoid of taste and smell, and smooth to the touch : insoluble in water, and infusible, except at a very intense heat ; is not acted upon by the pure alkalies, by which it is distinguished from alumina and glucina ; but is slightly soluble in carbonate of ammonia.

REFERENCES. *For the process for obtaining pure Yttria, see Ann. de Chim.* xxxvi. 150 ; *also, Henry, Brande and Berzelius.*

SECTION XI.

ZIRCONIUM.

Atom. Num. 30 ? *Symb.* Z.

The existence of the metallic basis of zirconia was rendered probable by Sir H. Davy, but the decomposition of this earth had not been effected in a satisfactory manner till the year 1824, when Berzelius succeeded in obtaining zirconium in an insulated state.

PROPERTIES. A powder as black as charcoal, which may be boiled in water without being oxidized, and is attacked with difficulty by sulphuric, muriatic or nitromuriatic acid, but is dissolved readily and with the disengagement of hydrogen gas, by hydrofluoric acid ; when heated in the open air, it takes fire at a temperature below redness, burns very brightly, and is converted into the earth ; when rubbed between two hard surfaces, it assumes the form of shining scales, of a dark gray colour.

PREPARATION. . The process for obtaining zirconium, is to heat a mixture of potassium and hydrofluate of zirconia and potassa, carefully dried, in a tube of glass, or iron, by means of a spirit lamp. The reduction takes place at a temperature below redness, and without emission of light. The mass is then washed with boiling water, and afterwards digested for some time in dilute muriatic acid. The residue is pure zirconium.—*Berzelius, Traité de Chim.* ii. 382.

ZIRCONIUM AND OXYGEN.

Oxide of Zirconium—Zirconia or Zircon.

Discovered in 1789 by Klaproth, in the *Jargon* or *Zircon* of Ceylon, and since found in the *Hyacinth* and in the *Eudialite* from Greenland.

PROPERTIES. An earthy substance resembling alumina in appear-

ance, of specific gravity 4·3, having neither taste nor odour, and quite insoluble in water, its colour, when pure, is white, but it has frequently a tinge of yellow, owing to the presence of iron, from which it is separated with great difficulty.

The composition of zirconia has not yet been satisfactorily determined. From some analyses of Berzelius, it is probable that the atomic weight of this earth is about 30 or 33.

A process for obtaining pure zirconia is described by MM Dubois and Silveira.

REFERENCES. *Webster's Brande, and Henry's Chem.* i. 661. *See also, Berzelius, Traité de Chim., where a Sulphuret and a Carburet of Zirconium are described.*

TESTS OF THE SALTS. The salts of zirconia are distinguised from those of alumina and glucina, by being precipitated by all the pure alkalies, in an excess of which it is insoluble. The alkaline carbonates precipitate it as carbonate of zirconia, and a small portion of it is redissolved by an excess of the precipitant.

SECTION XII.

SILICIUM.

Atom. Num. 7·5—*Symb.* Si.

That silica, silex or silicious earth, is composed of a combustible body combined with oxygen, was demonstrated by[Sir H. Davy; but pure silicium was first obtainad by Berzelius in 1824, by the action of potassium on fluosilisic acid gas.

PROPERTIES. Colour dark brown, without the least trace of metallic lustre ; a non-conductor of electricity ; incombustible in air and in oxygen gas, and may be exposed to the flame of the blow-pipe without fusing or undergoing any change ; soluble in a mixture of nitric and hydrofluoric acids. For other properties, mode of preparation, &c. *see Berzelius, Traité de Chim.* i. 367.

Some uncertainty still prevails with regard to the true nature of silicium. As it wants the metallic lustre and is a non-conductor of electricity, it cannot perhaps be regarded as a metal ; and hence Berzelius, Thomson, and others, place it with carbon and boron, among the non-metallic combustibles. Until these properties, however, are more completely established, it may be proper to retain it in the present class, more especially as silica is so nearly allied to the oxides of the metals which have just been noticed.

SILICIUM AND OXYGEN.

Oxide of Silicium.—Silica or Silex.—Atom. Num. 15·5—*Symb,* O+Si.

PROPERTIES. When artificially prepared it is a perfectly white and tasteless powder, insipid, inodorous, and feeling harsh between the fingers ; insoluble in water, and not acted on by any acid except the

hydrofluoric ; it is fixed in the fire, and is very infusible, but fuses before the oxy-hydrogen blow-pipe with greater facility than lime or magnesia ; when recently prepared and very minutely divided, it is taken up by the fixed alkalies, and hence by some chemists termed *Silicic Acid,* and its compounds with alkaline bases, *Silicates ;* when mixed with carbonate of potassa, and exposed to strong heat, it forms *glass,* and when the alkali is added in excess, a compound is obtained, formerly termed *Liquor Silicium* or *Liquor of Flints.*

It is insoluble in water.—This is true when silica is in the solid form ; but Berzelius has shown that, when silica in the nascent state is in contact with that fluid, it is dissolved in large quantity. On evaporating the solution gently, a bulky gelatinous substance separates, which is the *Hydrate of Silica.* This hydrate is partially decomposed by a very moderate temperature ; but a red heat is required for expelling the whole of the water. According to Dr. Thomson, silica unites with water in several proportions.—*First Prin.* i. 191.

When mixed with carbonate of potassa and subjected to heat, it forms glass.—It is owing to the silicious earth which it contains, that glass is decomposed by the hydrofluoric acid. Glass, however, has occasionally other ingredients besides the two that have been mentioned, the object of which admixtures is to adapt it to particular purposes. *Flint glass* is formed of fine silicious sand, pearlash, litharge or minium, a little nitre, and a small quantity of manganese ; *Crown glass,* for windows, of soda, fine silicious sand, lime, and fragments of glass ; *Green bottle glass,* of sand, kelp, pearlash, clay, and fragments of glass ; and *Plate glass,* of fine sand, soda, lime, manganese, oxide of cobalt, and fragments of glass.* *Pastes* or *artificial gems,* are only another variety of glass, into the composition of which, borax usually enters, the colours being given by various metallic oxides.—*Henry,* i. 667.

NATIVE STATE AND PREPARATION. Silica exists in the earth in great quantity. It enters into the composition of most of the earthy minerals ; and under the name of quartz rock, forms independent mountainous masses. It is the chief ingredient in sandstones ; and flint, calcedony, rock crystal, and other analogous substances, consist almost entirely of silica.† Siliceous earth of sufficient purity for most purposes may, indeed, be procured by igniting transparent specimens of rock crystal, throwing them while red hot into water, and then reducing them to powder.—*Brande.*

USES. The most important application of silex, is to the manufacture of glass ; but it is also of use in the composition of porcelain ; for, absolutely pure clay, without an admixture of silicious earth, would shrink too much to be fit for the uses of the potter. When mixed with

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* It is of some importance to the analyst to be aware that glass to a certain extent is decomposable by water. If some of it in a powdered state be triturated with distilled water, in a short time the turmeric test will indicate a portion of alkali in solution.

† Corn and grasses contain silex and sufficient potash to form glass. A very pretty experiment may be made on these plants with a blow-pipe. If you take a straw of wheat, barley, or hay, and burn it, beginning at the top and heating the ashes with the blue flame, you will obtain a perfect globule of hard glass fit for microscopic experiments.—*Davy.*

slaked lime it forms *mortar*, which is used as a cement for building. According to Dr. Higgins the best proportions are three parts of fine sand, four parts of coarser sand, one part of quicklime recently slaked, and as little water as possible. The stony hardness which mortar acquires has been ascribed to the absorption of carbonic acid, and to a combination of part of the water with the lime. But I concur in the suggestion of Mr. Donovan that it is rather to be ascribed to a sort of chemical union of the silica and lime; a theory which accounts for the hardness of mortar in the interior of thick old walls, where carbonic acid could scarcely have penetrated, and which scarcely effervesces when treated with acids. [On this subject see *Thomson Inorg. Chem.* i. 440, *and Donovan Chemistry*, 257.]

REFERENCES. *Faraday's process for obtaining Silica, Chem. Manip.* —*For a good account of the different varieties of Glass, see Aikin's Dict. of Chem. art. Glass ; and Guyton Morveau, in Ann. de Chim.* lxxii. *or Report. of Arts*, 2d *ser.* xix. 307, 368. *Dumas, Chim. appl. aux Arts. The volume on Porcelain and Glass, in Lardner's Cyclopædia.*

Chloride of Silicium.—When silicium is heated in a current of chlorine gas, it takes fire and is rapidly volatilized. The product of the combustion condenses into a liquid, which appears to be naturally colourless, but to which an excess of chlorine communicates a yellow tint. This fluid is very limpid and volatile, and evaporates almost instantaneously in open vessels in the form of a white vapour. It has a suffocating odour not unlike that of cyanogen, and when put into water is converted into muriatic acid and silica, the latter being easily obtained in the gelatinous form.—*Berzelius, Traité de Chim.* i. 374.

Bromide of Silicium.—This compound may be obtained in the same way as that just described, merely substituting the vapour of bromine for chlorine. When purified from free bromine by mercury, and redistilled, it is a colourless liquid, which emits dense vapours in an open vessel, being decomposed by the moisture of the air, and is denser than strong sulphuric acid. At 302° F. it enters into ebullition, and freezes at 10°. Potassium when gently heated, acts on it with so much energy that detonation ensues. By water it is resolved into hydrobromic acid and silica.—*Phil. Mag. and Ann.* xi. 395.

Fluosilicic Acid.—*Atom. Num.* 26·18—*Symb.* F+S.

SYN. *Silicated Fluoric Acid. Fluoride of Silicium.*

PROPERTIES. A colourless gas, which extinguishes flame, destroys animals that are immersed in it, and irritates the respiratory organs powerfully; it does not corrode glass vessels provided they are quite dry; when mixed with atmospheric air it forms a white cloud, owing to the presence of watery vapour; specific gravity according to Thomson, 3·61 ; is powerfully acted on by water, which dissolves about 365 times its volume, [*Davy, Phil. Trans.* 1812,] and during absorption depositing silica.

PREPARATION. This gas is formed whenever hydrofluoric acid comes in contact with silicious earth; and this is the reason why pure hydrofluoric acid can be prepared in metallic vessels only, and with fluor spar that is free from rock crystal. The most convenient method of procuring the gas is to mix in a retort one part of pulver-

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ized fluor spar with its own weight of sand or pounded glass, and two parts of strong sulphuric acid. On applying a gentle heat, fluosilicic acid gas is disengaged with effervescence, and may be collected over mercury.

This compound is probably a fluoride of silicium and does not possess acid properties ; but when dissolved in water it is converted into *Silico-hydrofluoric Acid*, by the decomposition of the water, the hydrogen combining with the fluorine, the oxygen with the silicium.

The *Silico-hydrofluoric Acid*, or as it is also called *Silicated Fluoric Acid*, unites with bases and forms compounds which have been investigated by Berzelius.—*Ann. of Phil.* xxiv. 450.

Sulphuret of Silicium.—A white earthy looking substance, formed by heating silicium in the vapour of sulphur. By the action of water it is instantly converted into sulphuretted hydrogen and silica, the former escaping with effervescence, the latter dissolved in large quantity.

Carburet of Silicium.—When silicium is reduced by means of potassium, prepared by heating to redness carbonate of potassa with charcoal and afterwards purifying it by fusion, there results a mixture of silicium and carburet of silicium. This compound is of a darker colour than the pure silicium and by combustion affords carbonic acid. —*Berzelius, Traité de Chim.* i. 375.

Silicate of Lime.—found native and known to mineralogists by the name of *Tabular Spar*, or *Schaalstein*. The mineral called *Apophyllite* or *Ichthyopthalmite*, is a silicate of lime with a portion of silicate of potassa and water.

SECTION XIII.

THORIUM.

Atom. Num. 59·6 ?—*Symb.* Th.

The metallic basis of thorina, a new earth discovered by Berzelius, in 1829.

PROPERTIES. A gray metallic powder, incapable of decomposing water, but which when heated above redness, burns with a splendour nearly equal to that of the combustion of phosphorus in oxygen ; it is but slightly acted upon by nitric or sulphuric acid, but muriatic acid dissolves it with brisk effervesence.

This metal is obtained by decomposing chloride of thorinum by means of potassium.—*Berzelius, Traité de Chim.* ii. 391.

THORIUM AND OXYGEN.

Oxide of Thorium or Thoria.—*Atom. Num.* 67·6 ?—*Symb.* O+Th.

A constituent of a new mineral found in Brevig, in Norway, to which Berzelius has given the name formerly applied to a substance

erroneously supposed by him to be an earth, but which he afterwards ascertained to be a phosphate of yttria.

PROPERTIES. Thoria is white and irreducible by charcoal and potassium ; specific gravity 9·4 ; when strongly ignited is not attacked by any of the acids except the concentrated sulphuric ; dissolves readily in carbonate of ammonia, and on heating the solution a portion of the earth is precipitated, but is afterwards re-dissolved as the solution cools.—*Berzelius.*

CLASS IV.

METALS, WHICH DECOMPOSE WATER ONLY WHEN THEY ARE HEATED TO REDNESS.

SECTION XIV.

MANGANESE.

Atom. Num. 27·7—*Symb.* Mn.— *Sp. gr.* 6·85.   Bergman. 8·013 John.

Although this substance has been long known, its nature was not understood.   By the older chemists it was generally considered as an ore of iron.   It was proved to be a distinct metal by Scheele and Gahn in 1774.—*Scheele's Chem. Essays.*

PROPERTIES.   A hard brittle metal, of a grayish white colour and granular texture ; when pure is not attracted by the magnet ; is exceedingly infusible, requiring a heat of 160° Wedgewood for fusion ; soon tarnishes on exposure to the air, and absorbs oxygen with rapidity when heated to redness in open vessels ; it is said to decompose water at common temperature, with disengagement of hydrogen gas, though the process is exceedingly slow, but at a red heat decomposition is rapid, and protoxide of manganese is the result.

EXTRACTION.   Manganese, owing doubtless to its powerful affinity for oxygen, has never been found in an uncombined state in the earth ; but the peroxide of manganese occurs abundantly.   This metal retains its oxygen with such force that its oxides require a stronger heat for reduction than potassa or soda.   The method by which Ghan succeeded in procuring metallic manganese, was by exposing the peroxide, surrounded with charcoal, to the most intense heat of a smith's forge ; and this process has been successfully repeated by others.— [*Berthier, in Ann. de Chim. et de Phys.* xx.— *Turner.*]   Dr. Thomson recapitulates several processes for obtaining metallic manganese.— *Inorg. Chem.* i. 512.

MANGANESE AND OXYGEN.

Much labour has been employed by chemists in the investigation of the oxides of manganese, a subject of greater difficulty than might have been supposed.   Those who have contributed most to our knowledge concerning them, are John, Berzelius, Forchhammer, Bertheir, Arfwedson, Thomson and Turner.

The following are now recognized as distinct compounds of oxygen and manganese :

	O. Mn.		
Protoxide,	$8+27.7$ or	O+	Mn.$= 35.7$
Sesqui-oxide,	$12+27.7$	$30+2$Mn.$= 79.4$	
Peroxide,	$16+27.7$	$20+$ Mn.$= 43.7$	
Red oxide,	$10.66+27.7$	$40+3$Mn.$=115.1$	
Varvicite,	$14+27.7$	$70+4$Mn.$=166.8$	
Manganeseous acid,	$24+27.7$	$30+$ Mn.$= 51.7$	
Manganesic acid,	$28+27.7$	$70+2$Mn.$=111.4$	

Protoxide of Manganese.—Atom. Num. 35.7—*Symb.* O+Mn.

PROPERTIES. When pure, of a mountain green colour ; according to Turner undergoing no change by exposure to air for nineteen days ; at 600° F. is oxidized with considerable rapidity, and at a low red heat is converted in an instant into the red oxide ; unites readily with acids and forms colourless salts.

PREPARATION. This oxide may be formed as was shown by Berthier, by exposing peroxide, sesquioxide or red oxide of manganese to the combined agency of charcoal and a white heat ; or by exposing either of the oxides of manganese contained in a tube of glass, porcelain, or iron, to a current of hydrogen gas at an elevated temperature, as described by Dr. Forchhammer.—*Ann. of Phil.* xvii. 52.

Sesquioxide of Manganese.—Atom. Num. 79.4—*Symb.* 3O+2 Mn.

PROPERTIES. Colour brownish or nearly black, depending upon the source from whence it is obtained ; it is acted upon by sulphuric and nitric acids ; when exposed to the air absorbs oxygen and is converted into the peroxide.

NATIVE STATE AND PREPARATION. This oxide occurs nearly pure in nature, and as a hydrate it is found abundantly, often in large prismatic crystals, at Ihlefeld in the Hartz. It may be formed artificially by exposing peroxide of manganese for sometime to a moderate red heat, and is therefore the chief residue of the usual process for obtaining oxygen gas ; but it is difficult so to regulate the degree of the duration of the heat, that the resulting oxide shall be quite pure.

Peroxide of Manganese.--Atom. Num. 43.7—*Symb.* 2O+Mn.

A very abundant ore, commonly called *Black Oxide of Manganese*, the nature of which was demonstrated by Scheele, in 1774.

PROPERTIES. Occurs massive, of an earthy appearance, mixed with various other substance, or in the form of minute prisms ; it is unchanged by exposure to the air ; is insoluble in water ; does not unite with acids or alkalies ; yields oxygen gas when heated to redness, or when boiled with sulphuric acid, in the former case it is converted into the sesquioxide, in the latter a sulphate of the protoxide is formed.

USES. This oxide is employed in the arts for discolouring glass, and in preparing chlorine for bleaching. In the laboratory it is used for

procuring chlorine and oxygen gases, and in the preparation of the salts of manganese.

Red Oxide of Manganese and Oxidum manganoso-manganicum of Arfwedson. These Dr. Turner has shown to be identical. The oxide of Arfwedson occurs as a natural product, the other may be formed artificially by exposing the peroxide or sesquioxide to a white heat, either in close or in open vessels. Its colour is variable, but when rubbed to the same degree of fineness, it is always of a brownish red colour when cold, and nearly black, while warm. It does not change its state of oxidation by being ignited in contact with air. It dissolves in muriatic acid, with a disengagement of chlorine, and communicates a deep red colour to the acid, which disappears on keeping.

The red oxide contains more oxygen than the protoxide, and less than the deutoxide. Its elements are in such proportion that it may be regarded as a compound, either of two proportions of protoxide and one proportion of peroxide, or two proportions sesquioxide and one protoxide.— *Turner*.

Varvicite.—A compound known only as a natural production, having been first noticed a few years since by Mr. Phillips among some ores of manganese found in Warwickshire. In the colour of its powder and in its hardness it bears considerable resemblance to the peroxide of manganese for which it was at first mistaken. But it is readily distinguished from that ore by its stronger lustre ; its highly lamellated texture which is very similar to that of manganite, and by its yielding water freely when heated to redness. Its specific gravity is 4·531. —When strongly heated it is converted into red oxide, losing 5·725 per cent. of water, and 7·385 of oxygen. It is probably, like the red oxide, a compound of two other oxides ; and the proportions just stated justify the supposition that it consists of one atom of peroxide, and one of sesquioxide of manganese, united in the mineral with half an atom of water.— *Turner, Phil. Mag. and Ann.* v. 209. vi. 281, and vii. 284.

REFERENCES. *Dr. John's Contributions towards a chemical knowledge of Manganese, Ann. of Phil.* ii. 272. *Berzelius, Traité de Chim.* iii. 296. *Gay Lussac, Ann. de Chim. et de Phys.* i. 39. *Thenard, Traité de Chim.* ii. 341. *Arfwedson, Ann. of Phil.* xxiii. 267. *Berthier, Ann. de Ch. et de Phys.* xx. *Thomson's First Prin.* i. 364. *Turner, in Phil. Trans. of Edin. for* 1828, *or Phil. Mag. and Ann.* iv. 22, 96.

Manganeseous and Manganesic Acids.

When the peroxide of manganese is mixed with an equal weight of nitre or carbonate of potassa, and the mixture exposed to a red heat, a green coloured fused mass is obtained, which has long been known by the name of *Mineral Chamelion*. On dissolving this substance in water, a green solution is obtained ; the colour of which soon changes in succession to blue, purple and red, and ultimately disappears entirely. The experiment may be varied by putting equal quantities of this substance into two glass vessels, and pouring in the one hot, and into the other cold water. The hot solution will have a beautiful green colour, and the cold a deep purple. The shades will vary as the temperature alters.

From the researches of Dr. Forchhammer it is probable that the green and red colours are produced by two distinct acids, the *Manganeseous* and *Manganesic*; one of which forms red and the other green coloured salts; and very recently Mitscherlich has established the existence of these acids and ascertained their composition. He proposes to distinguish them by the names of *Manganic* and *permanganic* acids, from the circumstance of his finding the green coloured salts isomorphous with the sulphates; and the red salts isomorphous with the perchlorates.—*Ann. de Chim. et de Phys.* xlix. 113. *Ann. of Phil.* xvi. 130. *Henry's Chem.* ii. 12. *See also Berzelius, Traité de Chim.* iii. 296, *and Unverdorben, in Phil. Mag. and Ann.* ii. 393.

MANGANESE AND CHLORINE.

Chemists are acquainted with two compounds of chlorine and manganese.

Protochloride of Manganese.—*Atom. Num.* 63·15—*Symb.* Cl+Mn.

PROPERTIES. A pink coloured semi-transparent substance; deliquescent, and, of course, very soluble in water, being converted by that fluid, with the evolution of caloric, into *Muriate of Manganese.*

PREPARATION. This chloride is best prepared by evaporating a solution of muriate of manganese to dryness, by gentle heat, and heating the residue to redness in a glass tube, while a current of muriatic acid gas is transmitted through it. The heat of a spirit lamp is sufficient for the purpose.

Perchloride of Manganese.—*Atom. Num.* 303·55—*Symb.* 7Cl+2 Mn.

A new compound discovered by Dumas.

PROPERTIES. A volatile compound, appearing when first formed, as a vapour, of a copper or greenish colour; but on traversing a glass tube, cooled to 5° or –4° F. is condensed into a greenish-brown coloured liquid; when the air of a large tube is displaced by the gas, and this is poured into a larger tube, the interior of the latter being first moistened with water, a dense rose-coloured fume appears, and the inside of the vessel acquires a deep purple colour; a circumstance caused by the instantaneous production of muriatic and manganesic acids.

PREPARATION. This chloride is easily prepared by putting a solution of manganese into a strong sulphuric acid, and then adding fused sea salt. The muriatic and manganesic acids mutually decompose each other; water and perchloride of manganese are generated, and the latter escapes in the form of vapour.

REFERENCES. *Dumas, in Ann. de Chim. et de Phys.* xxxvi. 81, *or Edin. Jour. of Science,* viii. 179.

MANGANESE AND FLUORINE.

Fluoride of Manganese.—Atom. Num. 186·16*—Symb.* 7 F+2 Mn.

Discovered by Dumas and Wohler, and described in *Ann. de Chim. et de Phys. Jan.* 1828.

PROPERTIES. A gaseous compound or vapour, of a yellowish-green colour ; when mixed with atmospheric air, it acquires instantly a beautiful purple red colour ; is freely absorbed by water, yielding a solution of the same red tint ; it acts instantly on glass, with the formation of fluosilicic acid gas, a brown matter being at the same time deposited, which becomes of a deep purple red tint, on the addition of water.

PREPARATION. This compound may be prepared by mixing common mineral chamelion with half its weight of fluor spar and decomposing the mixture in a platinum vessel by fuming sulphuric acid.

Sulphuret of Manganese.—This compound may be procured by igniting the sulphate with one-sixth of its weight of charcoal in powder. [*Berthier.*] It is also formed by the action of sulphuretted hydrogen on the protosulphate at a red heat. [*Arfwedson.*] It occurs native in Cornwall and at Nagyag, in Transylvania. It dissolves completely in dilute sulphuric or muriatic acid, with disengagement of very pure sulphuretted hydrogen gas.— *Turner.*

Phosphuret and Carburet of Manganese, may be obtained by heating the metal in contact with phosphorus or carbon.—*Berzelius, Traité de Chim.* iii. 309.

MANGANESE AND THE METALS.

According to Berzelius manganese combines with silicium, gold, silver, copper and iron. The alloy of manganese and iron is whiter than iron, hard and brittle, and it is said to be most proper for the fabrication of steel.

SALTS OF MANGANESE.

Nitrate of Manganese.— Atom. Num. 152·7*—Symb.* (5O+N)+(O+Mn) +7 aq.

PROPERTIES. A salt with difficulty obtained in crystals ; colour similar to that of the carbonate ; it deliquiates rapidly when exposed to the air, and on the application of heat melts, and is immediately decomposed.

PREPARATION. This salt may be obtained by the action of dilute nitric acid upon protoxide of manganese, or by digesting peroxide of manganese in nitric acid, with some gum or sugar, which abstracts oxygen, carbonic acid is evolved, and the protoxide dissolved by the acid.

Sulphate of Manganese.—*Atom. Num.* 120·7—*Symb.* $(3O+S)+$
$(O+Mn.)+5$ aq.

PROPERTIES. A rose coloured salt, of a bitter styptic taste, very soluble in water; crystallizing in very flat rhombic prisms : at a bright red heat it gives out oxygen, and sulphurous acid and sesquioxide of manganese remain.

This salt is prepared by dissolving pure carbonate of manganese in moderately dilute sulphuric acid, and setting the solution aside to crystallize spontaneously.

With sulphate of ammonia, this salt yields a double *sulphate of ammonia* and *manganese*, consisting of one proportion combined with eight of water. It is isomorphous with the analogous salts of magnesia and protoxide of iron.—*Turner.*

Prosphate of Manganese.—*Atom. Num.* 89·4—*Symb.* $(2\frac{1}{2}O+P)+$
$(O+Mn.)+2$ aq.

PROPERTIES. A tasteless white powder, insoluble in water, and producing no alteration on vegetable blues ; when heated to redness gives out water, and leaves anhydrous phosphate.

This salt is obtained by mixing together solutions of sulphate of manganese and phosphate of soda. The phosphate of manganese precipitates in the state of a white powder, which may be collected on a filter, washed and dried in the open air.

Carbonate of Manganese.—*Atom. Num.* 75.7—*Symb.* $(2O+C)+$
$(O+Mn.)+2$ aq.

PROPERTIES. A snow white tasteless powder, insoluble in water, and when kept for some time is converted into black oxide of manganese.

This salt is prepared by adding a carbonated alkali to a salt with a base of protoxide of manganese. Dr. Turner thinks it probable that it is strictly anhydrous.

TESTS OF THE SALTS OF MANGANESE. The salts of manganese containing the protoxide, are mostly soluble in water, and the solution becomes turpid and brown by exposure to air. They are not precipitated by hydriodic acid; they furnish white precipitates with the alkalies, which soon become discoloured by exposure to air ; they are precipitated white by ferro-cyanate of potassa, and yellow by hydro-sulphuret of ammonia.

SECTION XV.

IRON.

Atom. Num. 28.— *Symb.* Fe.[*]—*Sp. gr.* 7·78.

Iron has been known from the most remote periods, and is the most diffused, the most abundant, and the most important of the metals. It was formerly called Mars, and hence the term *Martial* was applied to its compounds.

PROPERTIES. This metal has a bluish-white colour; it is susceptible of a high polish; it is very malleable, and is capable of being drawn into very fine wire, though not of being beaten into very thin leaves; in its pure state is exceedingly infusible, but this disadvantage is counterbalanced for all practical purposes, by its possessing the property of *welding* in high perfection; its hardness exceeds that of most of the metals, and it may be rendered harder than most bodies when converted into steel; it is attracted by the magnet and may itself have the magnetic virtue imparted to it.

Iron is malleable and ductile.—This metal is malleable in every temperature, and its malleability increases in proportion as the temperature augments; but it cannot be hammered out nearly so thin as gold or silver, or even copper. Its ductility, however, is more perfect, for it can be drawn out into wire as fine, at least, as a human hair.

It is acted on by the Magnet.—Iron is attracted by the magnet, and it is upon this principle that iron filings are often freed from sand and other impurities. [*See page* 88.] When perfectly pure, iron retains the magnetic virtue for a short time only, but when combined with carbon so as to form steel it may be rendered permanently magnetic.

NATIVE STATE AND EXTRACTION. Iron is rarely found native in its pure state; the meteoric iron being alloyed with nickel and cobalt. It is artificially procured by heating the native oxide with charcoal: but when thus obtained, it is never quite free from carbonaceous matter. The only method of preparing iron absolutely pure, is by passing dry hydrogen gas over the pure oxide, heated to redness in a tube of porcelain.

REFERENCES. *A notice of a mass of pure native Iron, found in Connecticut by Mr. Burrall, see Silliman's Jour.* xii. 154. *For a table of the principal Meteoric Stones which have fallen from* 1785 *to* 1815. *see Thenard's Traité de Chim.; also Cleaveland's Mineralogy. For an account of the various processes for extracting Iron from its Ores, see Aikin's or Ure's Chemical Dictionary.*

IRON AND OXYGEN.

Iron combines with oxygen in two proportions only, forming the blue or protoxide, and the red or peroxide. Both these compounds are capable of yielding regular crystalline salts with acids.

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* From the latin word *Ferrum.*

Protoxide of Iron.—Atom. Num. 36—Symb. O+Fe.

Although the existence of this compound was inferred some years since by Gay Lussac, it was first obtained in an insulated form by Stromeyer.

PROPERTIES. A compound of a dark blue colour, which when melted with vitreous substances, communicates to them a tint of blue; it is attracted by the magnet, though less powerfully than metallic iron; it is exceedingly combustible, for when fully exposed to air at common temperatures, it suddenly takes fire, and burns vividly, being reconverted into the peroxide; all its salts, particularly when in solution, absorb oxygen with such rapidity, that they may even be employed in eudiometry.

NATIVE STATE AND PREPARATION. This oxide is the base of the native carbonate of iron, and of the green vitriol of commerce. It may be obtained in an insulated form, by transmitting dry hydrogen gas over the peroxide of iron, at a very low temperature.

REFERENCES. *Gay Lussac, Ann. de Chim.* lxxx. 163; *Stromeyer, Edin. Jour. of Science,* v. 300.

Peroxide of Iron.—Atom. Num. 40—Symb. 1½O+Fe.

SYN. *Crocus Martis—Saffron of Mars.*

PROPERTIES. This oxide is of a brownish red colour, and is not attracted by the magnet; it forms salts generally of a red colour, the solutions of which are precipitated of a fine blue by ferro-cyanate of potassa, and of an intense bluish black, by infusion of galls.

NATIVE STATE AND PREPARATION. This oxide is an abundant natural product, known by the name of *Red Hematite,* occurring massive or crystallized. It may be artificially prepared by adding an alkali to a solution of iron in nitromuriatic acid; a brownish red hydrate subsides, which is identical in composition with the mineral called *Brown Hematite,* and consists of one proportion of peroxide, and one of water.

Black Oxide of Iron.—This substance, long supposed to be the protoxide of iron, contains more oxygen than the blue, and less than the red. It is most probably, not a definite compound of iron and oxygen, but is composed of the two real oxides, united in a proportion which is by no means constant. [*Turner.*] It occurs native, frequently crystallized in the form of a regular octahedron, which is not only attracted by the magnet, but is itself sometimes magnetic, and is then known under the name of *Magnetic Iron Ore,* which is abundant in various parts of our country. Another variety of this oxide is called *Iron Glance* and *Micaceous Iron Ore.* Iron is extracted from these ores, after they are roasted and reduced to powder, by mixing them with a certain quantity of limestone, and subjecting the whole to a high heat, with charcoal or coke. The carbonaceous matter deprives the ore of its oxygen, while the lime acts as a flux by combining with its impurities and forms a fusible compound called a *slag.* Sometimes the addition of sand is necessary to the formation of a fusible com-

pound with the ore and its impurities. In all cases the kind and the proportion of the flux must be determined by experiment.

This oxide is always formed when iron is heated to redness in the open air; and is likewise generated by the contact of aqueous vapour with iron, at elevated temperatures. But the composition of the product varies with the duration of the process and the temperature employed.

REFERENCES. *On the Oxides of Iron, see Berzelius, Traité de Chim.* iii. 249; *Thenard,* ii. 348; *Thomson's First Prin.* i. 343; *Mosander, Edin. Jour. of Science,* iv. 137.

IRON AND CHLORINE.

Iron and chlorine combine in two proportions, forming compounds first described by Dr. John Davy.—*Phil. Trans. for* 1812.

Protochloride of Iron.—*Atom. Num.* 63·45—*Symb.* Cl+Fe.

A compound of a gray colour, metallic splendour, and lamellated texture, requiring a red heat for its fusion, and converted by water into the *Protomuriate of Iron.* It is formed by dissolving iron in dilute muriatic acid, evaporating the solution to dryness, and igniting the precipitate out of contact of air.

Perchloride of Iron.—*Atom. Num.* 81·17—*Symb.* 1½ Cl+Fe.

A compound of a bright yellowish brown colour, crystallizing in small iridescent plates; it is volatile at a temperature a little above 212°; and when thrown into water is converted into the *Permuriate of Iron.* It is obtained by burning iron wire in an atmosphere of chlorine, or by evaporating the permuriate to dryness. This muriate is formed by digesting the peroxide of iron in muriatic acid, or by exposing the protomuriate to air. It forms the basis of the *Tinctura Muriatis Ferri* of the Pharmacopeia.

IRON AND BROMINE.

Bromides of Iron.—The union of these two substances may be effected by putting into a porcelain capsule any quantity of bromine with about twenty times its weight of water, and adding iron filings as long as any action continues, accompanied with gentle heat and agitation. If the solution is made and evaporated to dryness in close vessels, a protobromide is obtained; but if freely exposed to the air the perbromide is left.

IRON AND IODINE.

Protiodide of Iron.—Prepared by digesting iodine with water and iron wire, the latter being in excess; on evaporating the solution, without exposure to the air, to dryness, and heating moderately, the protiodide is fused and on cooling becomes an opaque crystalline mass of an iron gray colour and metallic lustre. It is deliquescent and very soluble in water and alcohol. To prevent its conversion into

periodide, a coil of iron wire should traverse the whole column of the solution. It is used in medicine as a tonic.

Periodide of Iron, of a yellow or orange colour according to the strength of the solution, is obtained by freely exposing a solution of the protiodide to the air, or digesting iron wire with excess of iodine, gently evaporating and subliming the periodide. It is a volatile red compound, deliquescent and soluble in water and alcohol.— *Turner.*

IRON AND SULPHUR.

Two compounds of these bodies are well known. Gay Lussac, however, contends for the existence of three; Arfwedson of four; and Berzelius of five. But these require to be further examined before they can be admitted as distinct atomic combinations.

Protosulphuret of Iron.— Atom. Num. 44— *Symb.* S+Fe.

PROPERTIES. A yellow, brittle substance, of a metallic lustre, which is feebly attracted by the magnet, and by exposure to air and moisture, is gradually converted into protosulphate of iron.

This sulphuret exists in nature, and is known to mineralogists, by the name of *Magnetic Iron Pyrites*. It may be prepared artificially by igniting the protosulphate of iron with charcoal; or still more conveniently, by heating a mixture of iron filings and sulphur.

Donovan recommends the following process for preparing the protosulphuret of iron for ordinary purposes. Mix 10 ounces of iron filings with 6 of flowers of sulphur; heat a crucible to a bright red, and having removed it from the fire, throw in the mixture. A kind of combustion commences round the margin next the crucible, and this extends slowly to the centre, the ignition being more intense every moment. When it has reached the centre, the combination is complete, and the ignition begins to diminish. When cold, the mass shrinks and may be extricated from the crucible, by mere inversion. It is of a deep gray colour with a shade of purple.

Bisulphuret of Iron.— Atom. Num. 60— *Symb.* 2S+Fe.

An abundant natural product known under the name of *Iron Pyrites*, but which cannot be artificially formed. It is of a bronze yellow colour, and is often found in crystals; when heated to redness it loses half its sulphur, and becomes converted into the protosulphuret.

REFERENCES. *Proust, on the native and artificial sulphurets of Iron, Jour. de Phys., or Repert. of Arts,* 1st ser. xvi. 411. *Thomson's Inorganic Chemistry,* i. 503, *contains a notice of five Sulphurets. Arfwedson, in Ann. of Phil.* xxiii. 341, *describes two new sulphurets. Gay Lussac, Ann. de Chim.* lxxx. 170. *Berzelius, Traité de Chim.* iii. 357.

IRON AND PHOSPHORUS.

Phosphuret of Iron.— A brittle, gray compound, which acts upon the magnet, and is formed by heating the phosphate of iron with charcoal, or by dropping phosphorus into a crucible containing red hot iron

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wire—*Hatchett, in Phil. Trans.* 1804. The *cold short* iron is supposed to owe its peculiar properties to the presence of phosphorus. Dr. Thomson describes three phosphurets of iron.—*Inorg. Chem.* i. 501.

IRON AND CARBON.

Carburets of Iron.—Carbon and iron unite in very various proportions ; but there are four compounds which are distinct from one another, viz. cast or pig iron, steel, cast steel, and graphite or plumbago.

Cast Iron, being the name applied to iron as it flows from the furnace in which it is reduced, contains among other ingredients, a very considerable, but variable proportion of carbon, amounting sometimes, to 1-40th of its weight. In this state it is neither ductile nor malleable, but very brittle ; and fuses with such facility at a red heat that it cannot be welded. It is highly crystalline and its texture is granular.

Cast iron may be converted into malleable or *Wrought Iron*, by exposure in a reverbatory furnace, to the combined action of heat and air, and subjecting the iron while still hot to the operation of rolling or hammering, by which its particles are approximated. But this, though the purest iron of commerce, still contains, according to Berzelius, a minute quantity of carbon.

There are three varieties of cast-iron commonly distinguished in commerce ; namely, *black cast-iron* usually called No. 1, *mottled cast-iron* called No. 2, and *white cast-iron*.

M. M. Gay Lussac and Wilson have published the results of a series of analyses of carbonaceous irons, which show the carbon in the bar irons examined to vary from fourteen to twenty-nine, and in the steels from sixty-two to ninety-three ten-thousand parts. In gray cast-iron it varied from sixteen to twenty-eight, and in white from twenty-three to twenty-seven thousand parts.—*Jour. of Science*, 1830.

Steel is made by exposing bars of the purest malleable iron, surrounded with charcoal in powder, to a long continued red heat. During this process, the iron unites with about 1-150th of its weight of carbon, and acquires new properties. It is much harder than iron ; is more sonorous and elastic, and takes a much higher polish, though it is less ductile and malleable. It bears a strong red heat and may be welded to iron. When combined with an additional quantity of carbon, it forms *Cast-Steel*, which is harder, more elastic and receives a higher polish than common steel, but is so fusible that it cannot be welded.

As has already been observed [page 172] diamonds when heated with soft iron, convert it into steel in the same manner as charcoal.

Steel may be distinguished from pure iron by applying a drop of dilute nitric acid to the surface, when the carbon which it contains will be exhibited by a black stain.

Wootz, or Indian steel, which is so valuable for the purpose of making edge tools, owes its excellence to combination with a minute portion of aluminum and silicium—[*Faraday, Brande's Jour.* vii. 288] and according to Stodart and Faraday, steel may be much improved for certain purposes, by being alloyed with silver, platinum, &c.—*Brande's Jour.* ix. 319.

Graphite or *Plumbago*, also known by the name of *Black Lead*, has an iron gray colour, metallic lustre, and granular texture ; and is generally stated to be a compound of 95 per cent. of carbon, with 5 of iron. But this is, perhaps, more correctly to be considered as a pure form of carbon. [See page 173.] It is an abundant native product, and is used in making pencils and crucibles, and in burnishing iron to protect it from rust.

REFERENCES. *Mushet on Iron and Steel, Tilloch's Phil. Mag.* ii. *The articles Iron Making, by D. Mushet ; and Cutlery, by Stodart, in the Supplement to the Encylopedia Britannica.*

IRON AND THE METALS.

According to Berzelius, iron forms alloys with most of the other metals. [*Traité de Chim.* iii. 284.] None of these, however, are of much importance, except tin plate, which will be described in the section on tin.

Ferrocyanic Acid.

PROPERTIES. This acid is neither volatile nor poisonous, in small quantities, and has no odour ; it is gradually decomposed by exposure to the light, forming hydrocyanic acid, and Prussian blue, but it is far less liable to spontaneous decomposition than hydrocyanic acid ; it reddens litmus permanently ; unites with bases and forms salts called *Ferrocyanates* or *Triple Prussiates ;* it separates carbonic and acetic acids from their combinations, and even decomposes some salts of the more powerful acids.

The chemical nature of this substance has engaged the attention of Mr. Porrett, Berzelius and Robiquet, but its true nature is still involved in some obscurity. The view of Mr. Porrett, which appears to be most consistent with the phenomena, is, that the elements of this acid are carbon, hydrogen, nitrogen and metallic iron, and he proposes for it the name of *Ferruretted Chyazic Acid.*

From the latest and best experiments on this subject it is probable that ferrocyanic acid is composed of

Hydrogen,	2 atoms = 2		Hydrocyanic Acid, 2 atoms=54	
Iron,	1 atom = 28	or of		
Cyanogen,	3 atoms = 78		Cyanide of Iron, 1 atom = 54	
	108			108

—*Ann. de Chim. et de Phys.* xvii. 197. xxii. 322.

PREPARATION. Mr. Porrett recommends two methods for obtaining ferrocyanic acid, by one of which it is procured in crystals, and by the other in a state of solution. The first process consists in dissolving 58 grains of crystallized tartaric acid in alcohol, and mixing the liquid with 50 grains of the ferrocyanate of potassa, dissolved in the smallest possible quantity of hot water. The bitartrate of potassa is precipitated, and the clear solution, on being allowed to evaporate spontaneously, gradually deposites ferrocyanic acid in the form of small cubic crystals of a yellow colour. In the second process, the ferrocyanate of baryta, dissolved in water, is mixed with a quantity of

sulphuric acid, which is precisely sufficient for combining with the baryta. The insoluble sulphate of baryta subsides, and the ferrocyanic acid remains in solution. According to Mr. Porrett, every ten grains of the ferrocyanate of baryta require so much liquid sulphuric acid as is equivalent to 2·53 grains of real acid.

REFERENCES. *Porrett on the Prussic and Prussous Acids, Repert. Arts,* 2d ser. xvi. 232, 273. *Porrett on the Ferruretted Chyazic Acid, Phil. Trans. for* 1814 *and* 1815. *Ann. of Phil.* v. 25. xii. 102. xiv. 295. *Robiquet, Ann. de Chim.* xii. 277, *or Brande's Jour.* ix. 179. *Berzelius, in Ann. de Chim. et de Phys.* xv. 144, *or Ann. of Phil.* xvii. *and* xviii. *Robiquet, Ann. de Chim. et de Phys.* xvii.

SALTS OF IRON.

Both of the oxides of iron combine with acids, and form distinct classes of salts.

Protonitrate of Iron.—Atom. Num. 15·3—*Symb.* $(5O+N)+(O+Fe)+$
7 aq.

PROPERTIES. Crystallizes in rhomboidal prisms, transparent and of a light green colour; reddens vegetable blues, as do all the soluble salts of iron; has a sweetish astringent taste, like that of protosulphate of iron, but harsher.

PREPARATION. This salt is obtained by dissolving iron in dilute nitric acid, till the acid refuses to take up any more of the metal. The solution is then to be concentrated under the exhausted receiver of an air pump, over sulphuric acid.— *Thomson's First Prin.* ii. 318.

Persesquinitrate of Iron.—Atom. Num. 193—*Symb.* $1\frac{1}{2}(5O+N)+$
$(1\frac{1}{2}O+Fe.)+8$ aq.

When nitrate of iron, as above prepared, is exposed to the atmosphere, it passes to the state of that in which the oxide is at the maximum; or we may obtain this salt by leaving nitric acid for a long time in contact with protoxide of iron. Crystals form spontaneously in the liquid, which are at first transparent and colourless, but become brown by keeping; their taste is acid and they redden vegetable blues. According to the analysis of Dr. Thomson they are constituted as above. —*First Prin.* ii. 328.

Protosulphate of Iron.—Atom. Num. 139—*Symb.* $(3O+S,+(O+Fe.)$
$+7$ aq.

PROPERTIES. This salt, commonly known by the name of *Green Vitriol* or *Copperas,* has a strong styptic, inky taste; it reddens vegetable blues; is insoluble in alcohol, but soluble in two parts of cold, and in three-fourths of its weight of boiling water; it occurs in right rhombic prisms, which are transparent and of a pale green colour; in its anhydrous state it is a dirty white powder.

This salt is sometimes found native, associated with iron pyrites; it is formed artificially by the action of dilute sulphuric acid on metallic iron, or by exposing the protosulphuret of iron in fragments to the

combined agency of air and moisture. It is largely used in the arts, especially in dyeing, and in the manufacture of ink-powder.—*See Aikin's Chem. Dict. and Henry's Chem.* ii. **33**.

Persesquisulphate of Iron.—Atom. Num. 100—*Symb.* $1\frac{1}{2}(3O+S)+ (1\frac{1}{2}O+Fe.)$

When a portion of protosulphate of iron is peroxidized by means of nitric acid, and cautiously concentrated till the whole of the nitric acid is dissipated, we obtain a red coloured mass, which dissolves only partially in water. The solution has a red colour with a tint of yellow— the taste is astringent and very harsh. When evaporated to dryness it speedily absorbs moisture, and deliquesces into a liquid. Alcohol dissolves it readily and it strongly reddens vegetable blues; and this is the salt to which Berzelius and Thomson have assigned the above constitution.

The portion remaining, after the above salt has been extracted, is a red coloured powder, destitute of taste and insoluble in water, to which Dr. Thomson has given the name, *Pertetrasulphate of Iron*—consisting of 1 atom sulphuric acid and 4 atoms peroxide of iron.

When the persulphate of iron is mixed with the sulphate of potassa, and the solution allowed to crystallize by spontaneous evaporation, crystals are obtained similar to common alum in form, colour, taste and composition. In this double salt, the sulphate of alumina is replaced by persulphate of iron, with which it is isomorphous.

A similar double salt may be made with a mixture of sulphate of ammonia and persulphate of iron.

Protophosphate of Iron, is a salt of a beautiful pale blue colour, soluble in most acids, and precipitated again by ammonia without change. It is found native both in the state of powder, and of fine blue crystals —and may be prepared artificially by mixing solutions of protosulphate of iron and phosphate of soda. It consists of one atom of protoxide of iron, and one atom of acid, with various proportions of water.

There are three species of phosphate of iron which occur native, viz. Hydrated phosphate of iron, Hydrated Subsesquiphosphate and Hydrated Diphosphate.

Perphosphate of Iron, is a yellowish white, insoluble powder, formed by mingling the solutions of persulphate of iron and phosphate of soda.

Protocarbonate of Iron.—Atom. Num. 58—*Symb.* $(2O+C)+(O+Fe.)$

This salt exists abundantly in nature. It occurs sometimes massive, sometimes crystallized in rhombs or hexagonal prisms. It is also contained in most of the chalybeate mineral waters, being held in solution by free carbonic acid. It is very difficult to form it artificially.

The *Subcarbonate of Iron*, of the London Pharmacopeia, consists of about 40 per cent. carbonate of iron, and 60 of the peroxide.—*Phillips.*

We are not acquainted with any compound of carbonic acid with the peroxide of iron.

The mineral known by the name of *Iron stone*, or *Clay iron* stone,

from which almost all the immense quantity of iron manufactured in England is smelted, is a carbonate of iron intermixed with more or less clay, coal and sometimes limestone.

Silicate of Iron.—The brown coloured hard slag from the smelting of copper ore, is either a silicate or bisilicate of iron, according to circumstances. There occur native no fewer than six species of silicated iron minerals.

Ferrocyanate of Potassa, sometimes called *Triple Prussiate of Potassa.*—A perfectly neutral salt, which is soluble in less than its own weight of water, and forms large transparent four-sided tabular crystals, of a lemon-yellow colour ; it is inodorous, has a slightly bitter taste, but quite different from that of hydrocyanic acid, and is permanent in the air ; when heated to redness it is decomposed, nitrogen gas is disengaged, and cyanide of potassium, mixed with carburet of iron, remains in the retort.

This compound is best formed by digesting pure ferrocyanate of iron in potassa, until the alkali is neutralized, by which means the peroxide of iron is set free, and a yellow liquid is formed, which yields crystals of the ferrocyanate of potassa by evaporation. It is made on a large scale, in the arts, by igniting dried blood or other animal matters, such as hoofs and horns, with potash and iron.

There is much diversity of opinion concerning the constitution of this salt. In the form of crystals, it is most probably, as Berzelius supposes, a double cyanide of potassium and iron ; in solution, a ferrocyanate of potassa.—*See a discussion on this subject, by Mr. R. Phillips, in Phil. Mag. and Ann. i. 110, and also the references under Ferrocyanic Acid.*

The ferrocyanate of potassa is employed in the preparation of several compounds of cyanogen, and as a reagent for detecting the presence of iron and other substances.

Red ferrocyanate of Potassa.—Obtained by passing chlorine gas into a moderately strong solution of common ferrocyanate of potassa, which is to be continued until the solution ceases to produce any effect when added to a solution of peroxide of iron. The liquor is then to be concentrated to two-thirds of its volume, and set aside in a moderately warm stove to crystallize : after some time, brilliant and slender yellow crystals are obtained in the form of a rose ; by a second crystallization, very long needle-form crystals are procured in tufts.—These crystals are ruby-coloured, transparent and very brilliant ; their form appears to be elongated octahedrons.

The principal character of this salt is that of indicating the protosalts of iron, precipitating them blue or green, according to the proportion in solution ; and on the contrary not precipitating the per salts of iron. This reagent, according to M. Girardin, is much more sensible than the common ferrocyanate of potassa, for it is capable of detecting one 90,000th of protoxide of iron, while the latter salt does not detect more than one 1800th of the protoxide.

Ferrocyanate of Baryta, is soluble in water, and forms yellow crystals by evaporation. It is prepared by digesting purified Prussian blue with a solution of pure baryta, and is used in the formation of ferrocyanic acid.

Ferrocynate of the Peroxide of Iron.—This substance, which forms the basis of *Prussian Blue,* is insipid and inodorous, insoluble in water

and in acids, unless they are concentrated and heated ; it is rendered white by strong sulphuric acid ; is decomposed by the alkalies and alkaline earths, which unite with the ferrocyanic acid, and liberate the peroxide of iron ; is also decomposed by peroxide of mercury, giving rise to bicyanide of mercury ; at a temperature above 307° F. it takes fire and burns like tinder, leaving from 54 to 60 per cent. of the oxide of iron.—*Henry.*

This compound, which was an accidental discovery of a colour-maker of Berlin, in 1710, is formed by mixing ferrocyanate of potassa with a persalt of iron in slight excess, and washing the precipitate with water. The Prussian blue, of which this is the colouring mate-rial, is prepared by heating to redness dried blood, or other animal sub-stances, with an equal weight of pearlash, until the mixture has ac-quired a pasty consistence. The residue, which consists chiefly of cyanide of potassium and carbonate of potassa, is dissolved in water, and after being filtered, is mixed with a solution of two parts of alum and one part of the protosulphate of iron. A dirty greenish precipi-tate ensues, which absorbs oxygen from the atmosphere, and passes through different shades of green and blue, until at length it acquires the proper colour of the pigment.

The chemical changes which take place in this process are of a very complicated nature, and do not appear to be understood. According to Dr. Turner the precipitate which is at first thrown down, is occa-sioned by the potassa, and consists chiefly of alumina and the protox-ide of iron. The ferrocyanic acid is generated by the protoxide re-acting upon some of the hydrocyanic acid, so as to form water and cyanide of iron, the latter of which then unites with undecomposed hydrocyanic acid. The ferrocyanic acid, thus produced, combines with oxide of iron ; and when the latter has attained its maximum of oxi-dation, the compound acquires its characteristic blue tint. This chem-ist controverts the opinion of Dr. Thomson, that the protoxide of iron enters into the composition of Prussian blue. He states that, in every good specimen of Prussian blue which he examined, the ferrocyanic acid was in combination with peroxide of iron only.

REFERENCES. *The first published account of the method of preparing Prussian Blue, will be found in the Phil. Trans.* xxxiii. *Proust's Essay on Prussian Blue, Jour. de Phys. or Repert. of Arts, 1st ser.* xiii. 180. *Dr. Cooper on the Manufacture of Prussian Blue, Emporium of Arts,* iii. 456. *On the same subject, see Aikin's Chem. Dict.* ii. *Zol-lickoffer on the medicinal properties of the Prussiate or Ferrocyanate of Iron.*

TESTS OF THE SALTS OF IRON. The salts of iron are mostly soluble in water. Those in which the basis is the protoxide, afford a precipitate of a white hydrate, upon the addition of the pure alkalies, and a white carbonate, by alkaline carbonates, and a white ferrocyanate, by ferro-cyanate of potassa. The two former precipitates become first green and then red ; and the latter green and blue by exposure to the air.

The persalts give a blue precipitate with ferrocyanate of potassa, blood red with the sulphocyanate of potassa, and deep black with infu-sion of galls.

The separation of the oxides of iron and manganese is one of the most complex problems in analytical chemistry, and has engaged the attention of many chemists. Berzelius and Rose recommend, for this

purpose, succinate of soda, or ammonia, which throws down the iron, and leaves the manganese. For directions concerning the employment of this and other means of separating the oxides of these metals, *see Rose's Manual*, 55, *and Henry's Chem.* ii. 590.

. SECTION XVI.

ZINC.

Atom. Num. 32·5—*Symb.* Zn—*Sp. gr.* 7.

Zinc has long been known as a metal in China and India, but its extraction from its ores is a comparatively recent discovery in Europe. Henckel first extracted zinc from calamine about the year 1721; Von Swab obtained it by distillation in 1742, and Margraff published a process in the Berlin Memoirs in 1746.

PROPERTIES. This metal is of a brilliant white colour with a shade of blue; it is hard, being acted on by the file with difficulty; at low or high degrees of heat it is brittle; but at temperatures between 210° and 300° F. it is both malleable and ductile, a property which enables it to be hammered into sheets of considerable thinness; it fuses according to Mr. Daniell, at 773° F., and when slowly cooled, forms regular crystals; in its ordinary state it may be pulverized when hot, in a heated iron mortar, the pestle being also heated.— *Faraday.*

NATIVE STATE AND EXTRACTION. The zinc of commerce, sometimes called *Spelter*, is obtained either from *Calamine*, the native carbonate of zinc, or from the native sulphuret, the *Zinc Blende* of mineralogists. It is procured from the former by heat and carbonaceous matters: and from the latter by a similiar process after the ore has been previously oxidized by *roasting*, that is, by exposure to the air at a low red heat. When first extracted from its ores, it is never quite pure; but contains charcoal, sulphur, and several metals in small quantity. It may be freed from these impurities by distillation,—by exposing it to a white heat in an earthern retort, to which a receiver full of water is adapted.

USES. Metallic zinc, is employed in the laboratory, for the construction of voltaic instruments.—It has also been proposed for the purpose of culinary vessels,* pipes for conveying water, sheathing for ships, &c. but it is easily acted on by the weakest acids, and is even

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* Vessels of zinc have long been known to be favourable for obtaining a superior quantity of cream from new milk placed in them, and patents for the manufacture of diary utensils from this metal have been taken out in England and also in this country. The increase in the quantity of cream is probably owing to the fact that the acetic acid developed in milk by heat and rest, is taken up by the zinc; and thus the coagulation of the milk which would be produced by the action of the free acetic acid is prevented, and the milk by remaining more perfectly fluid, admits the easy ascent of the suspended cream. But the milk must at the same time become impregnated with a soluble and deleterious salt of zinc, and is unfit for use. Indeed the ease with which this metal is acted on by the weakest acids, constitutes an insurmountable objection to its employment for culinary purposes.—*See Lardner's Cyclopædia Manufactures in Metal.*

tually, though slowly, oxidized by long exposure to air and moisture. It is hence unfit for these uses. Zinc is, however, employed with advantage when rolled into large plates, as a substitute for lead and slates in the covering of buildings. Plates of cast zinc are also used as a substitute for slabs of stone in the art of multiplying drawings and engravings; a patent for this purpose having been secured in England. The art is called *Zincography.—See Repert. of Pat. Invent. Dec.* 1835.

REFERENCES. *On the treatment necessary to render Zinc malleable and ductile, see Sylvester, in Phil. Mag.* xxiii., *and the Patents granted to him in Rep. of Arts,* 2d ser. vii. 404. ix. 251. *On the danger attending the use of Zinc for culinary purposes, and for measures for liquids, &c. see the Reports of the Medical Faculty of Paris, &c. Ann. de Chim. or Rep. of Arts,* 2d ser. xxiii. 178, *and* xxv. 247. *Beck's Med. Juris.*

ZINC AND OXYGEN.

Oxide of Zinc.—Atom. Num. 40.5—*Symb.* O+Zn.

Formerly called *Flowers of Zinc—Pompholix—Nihil album—Philosopher's Wool, &c.*

PROPERTIES. White at common temperatures; but when heated to low redness it assumes a yellow colour, which gradually disappears on cooling; it is fixed in the fire and very difficult of fusion; is insoluble in water, and therefore does not affect the blue colour of plants; it is a strong salifiable base, forming regular salts with acids, most of which are colourless.

NATIVE STATE AND PREPARATION. This substance which is rare in nature, is found at Franklin, New Jersey. It may be formed by fusing zinc in open vessels. When the metal is heated to full redness in a covered crucible, it bursts into a flame as soon as the cover is removed, and burns with a brilliant white light. The combustion ensues with such violence, that the oxide as it is formed is mechanically carried up into the air, in which state it has a considerable resemblance to carded wool. By heating metallic zinc in an atmosphere of aqueous vapour, cautiously regulating the heat so as not to fuse the metal M. Haldat has obtained crystals of oxide of zinc, of a honey colour. almost transparent, and of a rhomboidal form.—*Ann. de Chim.* xlvi. 72.

Oxide of zinc is sometimes subtsituted for white lead in house painting. It preserves a good colour much longer than the latter, but is not so perfect a white.

Hydrated Oxide of Zinc.—May be obtained in crystals by uniting a rod of zinc and iron, and placing them in caustic ammonia in a close vessel. Gas is developed, and in a few days the inside of the vessel is covered with small transparent crystals, which are permanent in the air, and consist of one atom oxide of zinc+one atom water=49·5. [*Jour. of Science*, 1830, *p.* 204.] The oxide is also precipitated in the form of a hydrate, by the addition of a solution of pure potassa or ammonia to a solution of the sulphate of zinc.

According to Berzelius there is a *suboxide of Zinc,* and Thenard describes a *deutoxide;* but these do not appear to be recognized by other chemists.

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ZINC AND CHLORINE.

Chloride of Zinc.—Atom. Num. 67·95—*Symb.* Cl+Zn.

Formerly called *Butter of Zinc.*

PROPERTIES. A compound fusible under a dull red heat, and on cooling goes through several degrees of consistency, being viscid before it becomes solid; it is very deliquescent and by the action of water produces a *Muriate of Zinc.*

This chloride is obtained by burning leaf zinc in chlorine gas, or by adding muriatic acid to zinc, evaporating the residue to dryness and then heating it to redness in a glass tube. According to Dr. Thomson, if the application of heat be stopped at the right point, a muriate of zinc may be obtained, perfectly free from water, of which this compound and muriate of ammonia are the only examples.—*First Prin.* ii. 224.

ZINC AND IODINE.

Iodide of Zinc.—Atom. Num. 158·5—*Symb.* I+Zn.

A fusible and volatile crsytalline compound which, when exposed to the air, deliquesces and is converted into *Hydriodate of Zinc.* It is formed by the union of iodine and zinc.

ZINC AND SULPHUR.

Sulphuret of Zinc.—Atom. Num. 48·5—*Symb.* S+Zn.

This compound exists in nature under the name of *Blende,* and is frequently found in dodecahedral crystals, or in forms allied to the dodecahedron. Its structure is lamellated, its lustre adamantine, and its colour variable, being sometimes yellow, red, brown or black. It may be made artificially by heating to redness a mixture of oxide of zinc and sulphur, by decomposing sulphate of zinc by charcoal, or by drying the white precipitate obtained on adding hydrosulphuret of ammonia to a salt of zinc.

The native black *Blende,* called by the miners *Black Jack,* is an abundant mineral, and important as the source of the pure metal, which is obtained by roasting the ore, and afterwards exposing it to heat in proper distillatory vessels mixed with charcoal.

REFERENCES. *Thomson, on the composition of Blende, Ann. of Phil.* iv. 89. *On the methods of extracting the metal from this and other ores of Zinc, see Bishop Watson's Chem. Essays,* iv. 1. *Bergman's Works,* ii. 309, *and Aikin's Chem. Dict.* ii.

Phosphuret of Zinc, is a compound of a whitish colour, and a metallic lustre not unlike lead. It has some malleability, exhales a phosphoric smell, and at a high degree of heat, burns like common iron.

Cyanide or Cyanuret of Zinc.—This compound is obtained by Pelletier by precipitating sulphate of zinc by hydrocyanate of potassa; forming a triple hydrocyanate of zinc, which being well dried, and

calcined at a dull red heat, is converted into a cyanide of zinc. It always contains, however, cyanide of potassium.

The above or a similar compound has of late been employed in Germany, instead of the hydrocyanic acid, and it has obtained the reputation of possessing decided vermifuge powers.—*Majendie's Formulary.*

ZINC AND THE METALS.

Zinc is capable of furnishing *alloys* with most of the other metals. Of these the most useful, brass, will be mentioned in treating of copper. One part of zinc and about two and a half of mercury form the electrical amalgam. The zinc is to be heated so as to char paper but not to burn it, and the mercury then poured on it.

SALTS OF ZINC.

Iodate of Zinc, falls down in an insoluble powder, when iodate of potassa is added to sulphate of zinc.

Nitrate of Zinc.—Atom. Num. 148·5—*Symb.* $(5O+N)+(O+Zn)$
$+6$ aq.

A salt with an exceedingly disagreeable taste, and which may be obtained with difficulty in flat four-sided prisms, which deliquesce with great rapidity. It is prepared by the action of dilute nitric acid upon zinc, and subsequent evaporation.

Sulphite of Zinc.—A crystallizable salt, readily soluble in water, but not in alcohol ; obtained by dissolving zinc in sulphurous acid.

Sulphate of Zinc.—Atom. Num. 143·5—*Symb.* $(3O+S)+(O+Zn)$
$+7$ aq.

SYN. *White Vitriol.*

PROPERTIES. Taste bitter and styptic ; colour white ; it crystallizes by spontaneous evaporation, in transparent flattened four-sided prisms, the primary form of which is a right rhombic prism and isomorphous with epsom salts ; the crystals dissolve in two parts and a half of cold, and are still more soluble in boiling water ; it reddens vegetable blues, though, in composition, strictly a neutral salt ; when the crystals are deposited from a hot solution, they only contain, according to Thomson, three proportions of water.

NATIVE STATE AND PREPARATION. This salt is found native in places where the sulphuret of zinc occurs ; being probably the result of the decomposition of that ore. It is prepared artificially by the action of dilute sulphuric acid upon metallic zinc during the process for preparing hydrogen gas ; but for the purposes of commerce, it is made by roasting the native sulphuret of zinc in a reverbatory furnace. The English white vitrol, however, is prepared for the most part by the direct action of sulphuric acid on metallic zinc, and is much purer than that obtained by the decomposition of the sulphuret.—*Aikin's Chem. Dict.* ii.

ADULTERATION. Sulphate of zinc is almost always contaminated

with iron, and often with copper and lead. Hence the yellow spots which are visible on it ; and hence also the reason why its solution in water lets fall a dirty brown sediment. It may be purified by dissolving it in water, and putting into the solution a quantity of zinc filings; taking care to agitate occasionally. The zinc precipitates the foreign metals and takes their place. The solution is then to be filtered and the sulphate of zinc may be obtained from it in crystals by proper evaporation.— *Thomson.*

ACTION ON THE ANIMAL ECONOMY. In the dose of a scruple or a drachm, sulphate of zinc is the most immediate emetic we possess ; and it is to be inferred, that if larger doses are rejected, as is the fact, with equal rapidity, they will in general cause no more harm than the medicinal dose. In some instances, however, persons have suffered severely from over-doses of this salt, and a few have even perished. It has also been said to have proved fatal when applied externally.— *Christison on Poisons. Orfila, Toxicologie Generale.*

Phosphate of Zinc.—*Atom. Num.* 96·2—*Symb.* $(2 \downarrow O + P) + (O + Zn.)$

A white tasteless powder, insoluble in water and without effect on vegetable blues. It is obtained by boiling carbonate of zinc in phosphoric acid, after the acid has been saturated in the cold and applying heat to the resulting mass.

Dr. Thomson describes a *Biphosphate of Zinc,* formed by dissolving carbonate of zinc in excess of phosphoric acid.

Carbonate of Zinc.—*Atom. Num.* 80·5—*Symb.* $(2O + C) + (O + Zn)$
$+2$ aq.

A white and tasteless salt, found in nature, and commonly known by the name of *Calamine,* which occurs either anhydrous and crystallized, or amorphous, and most commonly stalactitical ; in which state, each atom of the carbonate is united with an atom of water.

It is artificially prepared by adding carbonate of potassa to sulphate of zinc. After the precipitate is well washed and dried, it is constituted as above stated ; but it is difficult to obtain it with exactly the due proportion of water. If dryed at 212° F. it is anhydrous.

Ferrocyanate of Zinc appears as a yellowish white precipitate on adding ferrocyanate of potassa to sulphate of zinc.

TESTS OF THE SALTS OF ZINC. The salts of zinc are mostly soluble in water, and the solutions are colourless and transparent ; they are not precipitated by hydriodic acid. Potassa, soda and ammonia, form white precipitates, soluble in excess of the alkali and in sulphuric acid. Hydrosulphuret of ammonia causes a white precipitate, which is either a hydrosulphuret of the oxide of zinc, or a hydrated sulphuret of the metal. The soluble phosphates, carbonates and borates, produce white precipitates.

SECTION XVII.

TIN.

Atom. Num. 57·9—*Symb.* Sn.* *Sp. gr.* 7·9.

This metal has been known from the remotest ages. It was in common use in the time of Moses, and was obtained at a very early period from Spain and Britain, by the Phenicians.

PROPERTIES. Tin has a white colour, and a lustre resembling silver; is not oxidized by the combined agency of air and moisture, though the brilliancy of its surface is soon impaired by exposure to the atmosphere; it is quite malleable, for the thickness of common tin-foil does not exceed 1·1000th of an inch; it is soft and inelastic, and when bent backwards and forwards, emits a peculiar crackling noise; at 442° F. it fuses, and if exposed at the same time to the air, its surface tarnishes, and a gray powder is formed; when heated to whiteness, it takes fire and burns with a white flame, being converted into the peroxide of tin.

Combustion of Tin.—If a red hot grain of metallic tin be thrown on a paper tray, it will divide into several smaller grains, which skip about the paper and burn with a very vivid light.

EXTRACTION. The tin of commerce, known by the name of *Block* and *Grain Tin*, is procured from the native oxide by means of heat and charcoal. The best grain tin is almost chemically pure, containing, according to Dr. Thomson, very minute quantities of copper and iron, and occasionally of arsenic. [*Ann. of Phil.* x. 166.] According to Thenard, the tin from Malacca is the only kind which is perfectly pure. [*Traité de Chim.* i. 372.] Tin foil is said to be almost always a compound of tin and lead.

TIN AND OXYGEN.

Tin appears to be susceptible of two degrees of oxidation. Both these oxides form salts by uniting with acids; but they are likewise capable of combining with alkalies.

Protoxide of Tin.—*Atom. Num.* 65·9—*Symb.* O+Sn.

PROPERTIES. A powder of a gray colour, indecomposable by heat; it is insoluble in water; when slightly heated in contact with atmospheric air or oxygen gas, it is converted into the peroxide with the evolution of heat and light; its salts not only attract oxygen from the air, but act as powerful deoxidizing agents; when added to a solution of gold, it occasions a purple coloured precipitate, the *purple of Cassius*, by which this oxide may be recognized with certainty.

PREPARATION. This oxide may be prepared by keeping tin for some-

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* From the latin word *Stannum.*

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time in a state of fusion in an open vessel. It may also be obtained by precipitation from the protomuriate of tin. But it is difficult to obtain it pure in consequence of the great attraction which it has for oxygen, and its consequent conversion into peroxide.

Peroxide of Tin.—Atom. Num. 73·9—*Symb.* 2O+Sn.

Sometimes called *Stannic Acid.*

PROPERTIES. When artificially prepared, peroxide of tin is white or yellowish-white, fusible and undecomposable by heat; it acts the part of a feeble acid, and unites with the pure alkalies forming soluble compounds which are called *stannates:* when melted with glass it forms *white enamel.*

NATIVE STATE AND PREPARATION. This oxide, from which nearly all the tin of commerce is extracted, abounds in Cornwall, Eng., Saxony and Bohemia, and in the peninsula of Malacca and the Island of Banca, in India. It is said also to occur in France and in Chili, in South America. In minute quantity it has been found in Goshen, Massachusetts, and in several other places. The specific gravity of this mineral is about 7.; its primitive crystal, is an octahedron with a square base. It is infusible and insoluble in acids. Its occurrence is altogether confined to the primary rocks.

The peroxide of tin may be prepared artificially by treating metallic tin with nitric acid slightly diluted with water. Violent effervescence takes place, and a white powder, the hydrated peroxide is produced. On washing this substance and heating it to redness, aqueous vapour is expelled and the pure peroxide of a straw-yellow colour remains. It may also be procured by precipitation from a solution of perchloride of tin by potassa, ammonia or the alkaline carbonates; but the bulky hydrate which results readily dissolves in sulphuric, nitric and muriatic acids; which is not the case with the hydrate obtained by the action of nitric acid upon metallic tin.

TIN AND CHLORINE.

Tin unites in two proportions with chlorine; and the researches of Dr. Davy leave no doubt of these compounds being analogous in composition to the oxides of tin.

Protochloride of Tin.—Atom. Num. 93·35— *Symb.* Cl+Sn.

A gray solid substance, of a resinous lustre, which fuses at a heat below redness, and when heated in chlorine gas, is converted into the perchloride. It is prepared either by evaporating the muriate of the protoxide to dryness and fusing the residue in a close vessel, or by heating an amalgam of tin with calomel.

Perchloride of Tin.— Atom. Num. 128·8—*Symb.* 2Cl+Sn.

SYN. *Butter of Tin. Fuming Liquor of Libavius.*

A colourless volatile liquid, which emits copious white fumes when exposed to the atmosphere; it has a strong attraction for water and is converted by that fluid into the *Permuriate of Tin.*

This chloride may be prepared either by heating metallic tin or the protochloride, in an atmosphere of chlorine, or by distilling a mixture of eight parts of tin in powder, with twenty-four of corrosive sublimate.

Both the chlorides of tin possess the characters of an acid, and are capable of combining with chlorine bases, though only a few of these salts have been hitherto investigated. They are denominated *Chloro-Stannates* by Dr. Thomson.—See his *Inorg. Chem.* ii. 824.

Tin also combines with bromine and iodine; with the former in two proportions.

TIN AND SULPHUR.

Protosulphuret of Tin.—*Atom. Num.* 73·9—*Symb.* S+Sn.

A brittle compound of a bluish gray colour and metallic lustre; fusible at a red heat, and assuming a laminated structure in cooling. It is best formed by heating sulphur with metallic tin.

Bisulphuret of Tin.—*Atom. Num.* 89·9—*Symb.* 2S+Sn.

A compound of a golden yellow colour, formerly called *Aurum Musivum*, or *Mosaic Gold*, made by heating a mixture of sulphur and peroxide of tin in close vessels.

By exposing a mixture of sulphur and protosulphuret of tin to a low red heat, Berzelius obtained a compound of one proportion of tin and one and a half of sulphur. If it be really a definite compound, it should be termed a *Sesquisulphuret*.

TIN AND THE METALS.

Most of the malleable metals become brittle and lose their ductility by combination with tin; and hence tin was formerly called *Diabolus Metallorum*.

The common *tin plate*, so extensively employed in the arts, may be considered as an alloy of tin and iron.

For forming this valuable article, the iron, after being rolled into thin sheets, is completely cleansed and freed from oxide, by being steeped in water acidulated with muriatic acid. It is afterwards plunged into a vessel of melted fat and oil. At the same time also, the tin is kept melted in an oblong rectangular vessel; and to preserve its surface from oxidation, a quantity of melted fat and oil is kept floating on it. The iron plates are then immersed in the tin for some time, and when withdrawn they are found to have a bright coating of tin. The dipping is repeated twice or more times, according to the thickness of the coat intended to be given, and also to produce a smooth surface, and between these processes the tin is equalized with a brush. —See *Bishop Watson's Chem. Essays, and Parkes' account of the Manufacture of Tin Plate, Manchester Memoir's*, iii. *N .S.*, or *Brande's Jour.* viii. 141.

When tin plate is exposed to the vapour of muriatic acid, or if the plate is washed with almost any dilute acid, it assumes the appearance of what is called *Crystallized* or *Watered Tin*. This article is extensively employed to cover ornamental cabinet work, dressing boxes,

&c. and is the *Fer blanc moiré* of the French.   The best acid solutions
for this purpose, are 2 parts of nitric acid, 3 parts of muriatic, and 8
of water, or citric acid dissolved in a sufficient quantity of water.—
The watered tin is a true crystallization of the alloy ; and the process
is much improved by heating the plate in different parts by means of a
blow-pipe, or by raising the temperature of the whole plate to near red-
ness, and then pouring the cold acid mixture upon it, or plunging the
plate into the liquor.— *Thenard,* i. 635.   *Brande's Jour.* v. 368.

SALTS OF TIN.

Iodate of Tin.—An orange coloured substance formed either by the
direct combination of tin with iodine, or by adding hydriodic acid to
protomuriate of tin.   The proportion of its elements has not been de-
termined.

Protomuriate of Tin.—Atom. Num. 111·35— *Symb.* (Cl+H)+(O+Sn.)
+1 aq.

This compound, when evaporated out of contact of air, is a white
salt which may be obtained in large oblique four-sided prisms, transpa-
rent, of a silky lustre, and acid to the taste, and to colour tests.

The protomuriate of tin may be obtained by boiling one part of tin
with two of muriatic acid, in a tubulated retort.   The solution has al-
ways an excess of acid, and is perfectly limpid and colourless.   It has
a tendency to acquire an additional proportion of oxygen, and should
therefore be preserved from contact with the air.   This property of
absorbing oxygen is so remarkable, that it may even be applied to eu-
diometrical purposes.   It has also the property of reducing to a mi-
nimum of oxidation, those compounds of iron, in which the metal is ful-
ly oxidized : for example, it reduces the red sulphate to the green.   It is
a test also of gold and platinum, and blackens the solution of corro-
sive sublimate.   With hydrosulphurets it gives a black precipitate.—
Henry's Chem. ii. 45.

REFERENCES.   *On the preparation of Muriate of Tin, see Berard, Ann.
de Chim.* xviii. 78, *or Nicholson's Jour.* xxvi. *and Chaudet, Ann. de Chim.
et de Phys.* iii. 376.

The muriates as well as the oxide of tin, are poisonous.—*Christison
on Poisons.*

Nitromuriate of Tin.—The nitromuriatic acid dissolves tin abun-
dantly, and with violent effervescence and so much heat that it is ne-
cessary to add the metal slowly by successive portions.   The solution
is apt to congeal into a tremulous gelatinous mass ; and if water be ad-
ded, it is partly decomposed, and some oxide separated.

This compound is supposed to be a *Permuriate of Tin.*   It is used to
heighten the colours of cochineal, gum-lac, and some other red tinc-
tures, from crimson to a bright scarlet.   It is prepared by artists with
that dilute nitric acid called single aqua-fortis, to each pound of which,
are added from one to two ounces of muriate of soda or ammonia.
This compound is capable of taking up about an eighth of its weight
of tin.—*Henry.*

Nitrate of Tin.—This may be formed by treating the metal with dilute nitric acid ; a yellow solution, which will not crystallize, is obtained ; when exposed to the air it absorbs oxygen, and peroxide of tin precipitates ; if evaporated, the peroxide falls, and a portion of nitrate of ammonia is formed, part of the water as well as of the acid being decomposed.

Sulphate of Tin.—When tin is boiled in sulphuric acid, a solution is obtained which deposits white acicular crystals. A protosulphate of tin is also precipitated by pouring sulphuric acid into protomuriate of tin.

TESTS OF THE SALTS OF TIN. These salts are mostly soluble in water, and are precipitated of an orange colour by hydriodic acid, and by hydrosulphuret of ammonia, provided no excess of acid be present. Solutions of chloride of gold and of corrosive sublimate, produce purple and black precipitates in the salts containing the protoxide, but none in those containing the peroxide. Ferrocyanate of potassa produces a white precipitate in solution of muriate of tin.

SECTION XVIII.

CADMIUM.

Atom. Num. 55·8—*Symb.* Cd.—*Sp. gr.* 8·604.

This metal was discovered in 1817, by Professor Stromeyer, of Gottingen, in an oxide of zinc, which had been prepared for medical use from an ore of zinc brought from Silesia. It has since been discovered by Dr. Clarke in the zinc ores of Derbyshire, and in the common zinc of commerce, and by Mr. Herapath in the zinc works near Bristol, England.

PROPERTIES. This metal is nearly as white as tin, but is somewhat harder and more tenacious ; it is very ductile and malleable, and susceptible of a high polish ; its specific gravity is 8·604 before being hammered, and 8·691 afterwards ; it melts at about the same temperature as tin, and is nearly as volatile as mercury, condensing into globules which have a metallic lustre; its vapour has no odour.

EXTRACTION. The process by which Stromeyer separates cadmium from zinc or other metals is the following. The ore of cadmium is dissolved in dilute sulphuric or muriatic acid, and after adding a portion of free acid, a current of sulphuretted hydrogen gas is transmitted through the liquid, by means of which the cadmium is precipitated as sulphuret, while the zinc continues in solution. The sulphuret of cadmium is then decomposed by nitric acid, and the solution evaporated to dryness. The dry nitrate of cadmium is dissolved in water, and an excess of carbonate of ammonia added. The white carbonate of cadmium subsides, which, when heated to redness, yields a pure oxide. By mixing this oxide with charcoal, and exposing the mixture to a red heat, metallic cadmium is sublimed.

A very elegant process for separating zinc from cadmium was proposed by Dr. Wollaston. The solution of the mixed metals is put into a platinum capsule, and a piece of metallic zinc is placed into it. If

cadmium is present, it is reduced, and adheres so tenaciously to the capsule, that it may be washed with water without danger of being lost. It may then be dissolved either by nitric or dilute muriatic acid. — *Turner*.

REFERENCES. *Stromeyer on Cadmium, Ann. of Phil.* xiii. 108, xiv. 279. *Dr. E. D. Clarke on the discovery of this metal in the Derbyshire ores of Zinc, Ann. of Phil.* xv. 272, *and* xix. 123. *Herapath on Cadmium, and the sources of procuring it in quantity, Ann. of Phil.* xix. 435.

CADMIUM AND OXYGEN.

Oxide of Cadmium.—*Atom. Num.* 63·8—*Symb.* O+Cd.

PROPERTIES. The oxide of cadmium is of an orange yellow colour, and fixed in the fire; it is insoluble in water, and does not change the colour of violets, but is a powerful salifiable base, forming neutral salts with acids; it is precipitated as a white hydrate by pure ammonia, but is redissolved by excess of that alkali; it is precipitated permanently by pure potassa as a hydrate, and by all the alkaline carbonates, as carbonate of cadmium.

The oxide of cadmium may be obtained by heating the metal in open air, and also by igniting the carbonate.

Chloride of Cadmium, crystallizes in small rectangular prisms, perfectly transparent, which effervesce when heated, and are very soluble. At high temperatures it sublimes in small micaceous plates.

Iodide of Cadmium forms large and beautiful hexahedral tables of a metallic or pearly lustre. At a high temperature the iodine escapes.

Sulphuret of Cadmium occurs native in some kinds of zinc blende, and is easily procured by the action of sulphuretted hydrogen on a salt of cadmium. It has a yellowish orange colour, and is distinguished from the sulphuret of arsenic by being insoluble in pure potassa, and by sustaining a white heat without subliming.

Phosphuret of Cadmium has a gray colour and feeble metallic lustre, is brittle and very little fusible.

CADMIUM AND THE METALS.

Cadmium unites readily with other metals, and forms brittle alloys. When these alloys are exposed to a very high temperature, the cadmium is volatilized. It also unites with mercury and forms an amalgam which has a silvery appearance, and crystallizes in octahedrons.—*Berzelius*.

SALTS OF CADMIUM.

Nitrate of Cadmium.—*Atom. Num.* 153·8—*Symb.* (5O+N)+(O+Cd.) +4 aq.

This salt crystallizes in needles or prisms, which are deliquescent.

Sulphate of Cadmium.—Atom. Num. 139·8—*Symb.* (3O+S)+(O+Cd.)
$$+4 \text{ aq.}$$

Crystallizes in large rectangular prisms, resembling sulphate of zinc, which are soluble in water, effloresce in the air, and at a gentle heat, lose their water of crystallization.

Phosphate of Cadmium.—Atom. Num. 108·5—*Symb.* (2½O+P)+
$$(O+Cd.)+1 \text{ aq.}$$

A pulverulent and tasteless salt; insoluble in water, and formed by mixing solutions of nitrate of cadmium and phosphate of soda.

Carbonate of Cadmium.—Atom. Num. 85·8—*Symb.* (2O+C)+(O+Cd.)

A white tasteless powder, having a certain resemblance in colour to white lead; it is insoluble in water, and readily decomposable by heat; it is destitute of combined water, but when dried in the open air, retains the fifth part of an atom of water, no doubt hygrometrically united to the salt.— *Thomson.*

REFERENCES. *For further information concerning the Salts of Cadmium, see the papers of Stromeyer above quoted, and Thomson's First Prin.* ii. 360.

SECTION XIX.

NICKEL.

Atom. Num. 29·5—*Symb.* Ni.—*Sp. gr.* 8·279.

Discovered by Cronstedt, in 1751, in the *Copper Nickel* of Wesphalia.

PROPERTIES. Nickel has a white colour, intermediate between those of silver and iron; is susceptible of a fine polish; is both ductile and malleable; its specific gravity after fusion is about 8·279, and is increased to near 9·0 by hammering; it is attracted by the magnet, and like iron and cobalt may be rendered magnetic; is exceedingly infusible, even more so than pure iron; suffers no change at common temperatures by exposure to air and moisture, but absorbs oxygen at a red heat, though not rapidly, and is partially oxidized.

EXTRACTION. The principal source from which nickel is obtained, is a substance called *Speiss*, an artificial arseniuret of nickel, which remains at the bottom of the crucibles in which zaffre is prepared. Various processes have been proposed for extracting the metal from this compound, of which that of Dr. Thomson is the most simple and perhaps as successful as any. It consists in reducing the speiss to powder and digesting it in a mixture of sulphuric and nitric acids. The crystals obtained by evaporation are free from arsenic, iron, bismuth and antimony, but are contaminated with a little cobalt and copper. The copper is to be precipitated from a watery solution of these crys-

tals by a current of sulphuretted hydrogen, and the oxide of nickel when washed, but still moist, is to be exposed to chlorine gas, which dissolves the oxide of nickel, leaving that of cobalt untouched. The muriate of nickel is easily converted into sulphate, by the addition of a due proportion of sulphuric acid, and the sulphate, by one or more crystallizations, is obtained pure. From this salt, dissolved in water, carbonate of nickel is precipitated by carbonate of soda, or potassa, and after being well edulcorated, is to be dried and calcined.

Metallic nickel may be prepared either by heating the oxalate in close vessels, or by the combined action of heat and charcoal, or hydrogen, on the oxide of nickel.

REFERENCES. *Thomson, in Phil. Mag. and Ann.* ii. 151. *Robiquet, in Ann. de Chim.* lxix. *Mill, in Ann. of Phil.* xix. 201. *Laugier, in Ann. de Chim. et de Phys.* ix.; *and Berthier, same work,* xxv. *and* xxxiii. *Berzelius, Traité de Chim.* iii. 210. *Hisinger and Murray's experiments on Niccolaneum, Ann. of Phil.* i. 116. *Dr. Clarke's method of obtaining pure Nickel by the compound blow-pipe, same work,* xiv. 142.

NICKEL AND OXYGEN.

Nickel seems to be susceptible of only two states of oxidation; but Berzelius describes three oxides.

Protoxide of Nickel.—Atom. Num. 37·5—*Symb.* O+Ni.

PROPERTIES. This is of an ash-gray colour, but when heated to whiteness, of a dull olive-green; it is not attracted by the magnet; is a strong salifiable base, and nearly all the salts have a green tint; is precipitated as a hydrate, of a pale green colour, by the pure alkalies, but is redissolved by excess of ammonia.

It is formed by heating the carbonate, oxalate or nitrate, to redness in an open vessel.

Peroxide of Nickel.—Atom. Num. 41·5—*Symb.* 1½O+Ni.

The peroxide of nickel is of a black colour, and is formed by transmitting chlorine gas through water, in which the hydrate of the protoxide is suspended. It does not unite with acids; is decomposed by a red heat, and with hot muriatic acid forms a proto-muriate, with disengagement of chlorine gas.

Nickel combines with chlorine, iodine, phosphorus, sulphur and carbon; but these compounds do not possess any very striking properties. According to Mr. Ross, the carburet of nickel is apt to form when nickel is reduced from its salts by carbonaceous matter. It resembles iodine, or micaceous iron ore.—*Ann. of Phil.* xviii. 62, 149; xix. 201.

NICKEL AND THE METALS.

Nickel may be alloyed with most of the metals, but few of them are peculiarly interesting. An alloy of iron and nickel has been found in all the meteoric stones that have been hitherto analyzed, however re-

mote from each other the parts of the world in which they have fallen. In these it forms from 1 1-2 to 17 per cent. of their weight.—It enters, also, into the composition of the masses of native iron discovered in Siberia and South America ; and was found by Mr. Brande to the extent of 3 per cent. in native iron brought from the arctic regions.— *Brande's Jour.* vi. 369, and ix. 323. *For an elaborate paper of Meteoric Stones by Prof. Berzelius, see Lond. and Edin. Jour. of Science, &c.* ix. 429.

Metoric iron has been imitated by fusing iron with nickel. The alloy of 90 iron with 10 nickel, is of a whitish yellow cast, and not so malleable as pure iron. The alloy with 3 per cent. of nickel is perfectly malleable, and whiter than iron. These alloys are less disposed to rust than pure iron ; but nickel alloyed with steel increases the tendency to rust.—*Stodart and Faraday, in Brande's Jour.* ix. 324.

An alloy of copper and nickel occurs in nature, and is known by the name of *Copper-nickel.* It is of a copper colour and in addition to its chief ingredients contains sulphur, iron and cobalt.

But the most important of the alloys of nickel, is the *Tutenag* or *Packfong* of the Chinese. It is a compound of copper, tin, zinc and nickel. It is malleable, and is employed in the fabrication of various utensils. Under the name of *German Silver,* the same or a similar alloy is now extensively manufactured in Europe and America. It usually possesses a yellowish shade of colour owing to its containing a large proportion of copper. A specimen of this kind was found to contain, copper 60·0, zinc 17·8, nickel 18·7, cobalt 3·5 = 100·00.—*Lond. and Edin. Jour. of Science, &c.* viii. 80. *For an account of the manufacture of Packfong, see Brewster's Edin. Jour. of Science,* N. S. i. 167.

SALTS OF NICKEL.

Nitrate of Nickel.—*Atom. Num.* 136·5—*Symb.* (5O+N)+(O+Ni.) +5 aq.

This salt crystallizes in four-sided oblique prisms ; has a green colour, and does not undergo any change by exposure to the air.— *Thomson's First Prin.* ii. 333.

Sulphate of Nickel.—*Atom. Num.* 140·5—*Symb.* (3O+S)+(O+Ni.) +7 aq.

This salt has a beautiful grass-green colour, and crystallizes in rhombic and in square prisms.— *Thomson.*

Phosphate of Nickel.—*Atom. Num.* 100·2—*Symb.* (2½O+P)+(O+Ni.) +3 aq.

A powder of a light pea-green colour, tasteless and insoluble in water. It is obtained by mixing together solutions of sulphate of nickel and phosphate of soda, in the atomic proportions.

Carbonate of Nickel.—A light green tasteless powder, insoluble in water, but dissolving with effervesence in acids ; formed by precipitating a solution of sulphate of nickel by carbonate of soda.

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REFERENCES. *Thomson on the Salts of Nickel, First Prin.* ii. 833, *and Inorg. Chem.* ii. 596.

TESTS OF THE SALTS OF NICKEL. The solution of these salts has a fine green colour, and affords a green precipitate with ammonia, soluble in excess of that alkali, when it assumes a blue colour. Hydriodate of potassa produces a very characteristic yellowish green precipitate ; and the ferrocyanate of potassa, one of a pale gray or greenish white.

SECTION XX.

COBALT.

Atom. Num. 29·5—*Symb.* Co.—*Sp. gr.* 8·538.

This metal appears to have been discovered by Brandt. It is met with in the earth, chiefly in combination with arsenic, known by the name of *Arsenical Cobalt*. It is also, according to Stromeyer, a constant ingredient in meteoric iron.

PROPERTIES. Cobalt is solid, hard and brittle ; of a reddish gray colour, and weak metallic lustre ; it fuses at about 130° of Wedgewood, and when slowly cooled it crystallizes ; is attracted by the magnet, and is susceptible of being rendered permanently magnetic ; absorbs oxygen when heated in open vessels ; is readily oxidized by nitric acid, but is with difficulty attacked by sulphuric or muriatic acid.

NATIVE STATE AND EXTRACTION. Cobalt is found in nature in the form of oxide, of sulphate, of arseniate, and in combination with many combustibles, especially with sulphur and arsenic. From the oxide, metallic cobalt may be obtained by heating it with charcoal, by passing over it a stream of hydrogen gas, or by heating strongly the oxalate of cobalt in close vessels.

REFERENCES. *Thomson, in Ann. of Phil.* xvii. 250. *For Trommsdorf's process for obtaining pure Cobalt, see Repert. of Arts,* 2d ser. ii. 153, iv. 126, *and* viii. 154. *Laugier's process for separating Cobalt and Nickel, is described in Ann. of Phil.* xiii. 38 ; *and in Brande's Jour.* ix. 181.

COBALT AND OXYGEN.

Chemists are acquainted with two compounds of oxygen and cobalt.

Protoxide of Cobalt.—*Atom. Num.* 37·5—*Symb.* O+Co.

This oxide is of an ash-gray colour, and is the basis of the salts of cobalt, most of which are of a pink blue ; it absorbs oxygen when heated in open vessels, and is converted into the peroxide. It may be prepared by decomposing carbonate of cobalt by heat, in a close vessel ; and may be easily recognized by giving a blue tint to borax when melted with it.

The substance known in the arts by the name of *Zaffre*, is an impure oxide of cobalt, prepared by exposing the native arseniuret of cobalt, in a reverbatory furnace, to the united action of heat and air. On heating this substance with a mixture of sand and potassa, a beautiful blue coloured glass is obtained, which when reduced to powder, is known by the name of *Small*. In this form it is much employed in the arts for communicating a similar colour to glass, earthen-ware, and porcelain. *For details concerning the preparation of this substance and its employment in the arts, see Aikin's Chem. Dict. and Parkes' Chem. Essays.*

Peroxide of Cobalt.—Atom. Num. 41·5—*Symb.* $1\frac{1}{2}O + Co$.

This oxide is of a black colour, and is easily formed from the protoxide in the way already mentioned. It does not unite with acids; and when digested in muriatic acid, the protomuriate of cobalt is generated with disengagement of chlorine. When strongly heated in close vessels, it gives off oxygen, and is converted into the protoxide.

This compound appears to form salts with bases, especially ammonia. Gmelin calls it *Cobaltic Acid.—Ann. of Phil. 2d ser.* ix. 69.

COBALT AND CHLORINE.

Cobalt takes fire when introduced in a finely divided state, into chlorine gas ; but the compound has not been examined.

COBALT AND SULPHUR.

According to Berzelius, cobalt combines in several proportions with sulphur, but the compounds do not appear to possess any peculiarly interesting properties.—*Berzelius, Traité de Chim.* iii. 232.

SALTS OF COBALT.

Muriate of Cobalt.—A deliquescent salt, of a blue-green colour; when a little diluted the solution becomes pink ; the pale pink solution, when written with, is scarcely visible ; but if gently heated, the writing appears brilliant and green, which soon vanishes, as the paper cools. This solution has been termed *Hellot's Sympathetic Ink.*

This salt may be prepared by digesting either oxide in muriatic acid. The sympathetic solution may be obtained by digesting one part of cobalt or of zaffre in a sand heat for some hours, with four parts of nitric acid. To the solution add one part of muriate of soda; and dilute with four parts of water. Characters written with this solution are illegible when cold ; but when a gentle heat is applied they assume a beautiful blue or green colour.

Nitrate of Cobalt, occurs in crystals, which have an acrid and bitter taste, redden vegetable blues, and deliquesce rapidly when exposed to the air. It is easily obtained by dissolving cobalt, or its oxide, in nitric acid.

Sulphate of Cobalt.—This salt has a deep red colour, and crystallizes in rhombic prisms, similar to the form of sulphate of iron. There is also a *Bisulphate.*

Phosphate of Cobalt, is formed by dissolving the carbonate in phosphoric acid and adding alcohol, or by mixing muriate of cobalt and phosphate of soda. A lilac precipitate in the last case falls, which if mixed with eight parts of fresh precipitated alumina and dried, forms, according to Thenard, a blue pigment that may be substituted for *Ultra-marine*, and is known by the name of *Thenard's Blue*, or *Cobalt Blue*. *For a full description of the process, see Brande's Jour.* xv. 381; *Thenard's Traité de Chim.; and Franklin Jour.* ii. 3.

Carbonate of Cobalt.—A light powder, of a pink colour, tasteless, insoluble in water, and not altered by exposure to the air. It does not alter vegetable blues, but dissolves in acids with a strong effervescence. It is formed by decomposing the nitrate, muriate or sulphate of cobalt with carbonate of potassa, and washing and drying the precipitate.

REFERENCES. *Thomson on the Salts of Cobalt, First Princip.* ii. 341.

TESTS OF THE SALTS OF COBALT. All the salts of cobalt contain the protoxide; oxalic acid throws down from their solutions a rose-coloured precipitate; ferrocyanate of potassa one of a grass green colour; solution of borax a pink compound; and hydrosulphuret of ammonia a black hydrosulphuret of cobalt.—*Henry.*

CLASS V.

**METALS, WHICH DO NOT DECOMPOSE WATER AT ANY TEM-
PERATURE, AND THE OXIDES OF WHICH ARE NOT REDUCED
TO THE METALLIC STATE BY THE SOLE ACTION OF HEAT.**

ORDER I.

METALS, WHICH, WHEN COMBINED WITH OXYGEN, FORM ACIDS.

SECTION XXI.

ARSENIC.

Atom. Num. 37·7—*Symb.* As.—*Sp. gr.* 5·70.

This metal was known to the ancients, its combination with sulphur being noticed by Dioscorides, under the name of *Sandarac.* Its peculiar nature, however, was first demonstrated by Brandt, in 1733.

PROPERTIES. An exceedingly brittle metal, of a strong metallic lustre, and steel gray colour ; its structure is crystalline ; at 356° F. it volatilizes without being fused, and in close vessels may be collected unchanged ; but, when thrown on a red hot iron, it burns with a blue flame and a white smoke, and a strong smell of garlic is perceived, which belongs only to the metal and not to its oxides ; it is speedily tarnished by exposure to air and converted into a black powder, often known by the name of *fly powder,* which is generally considered as a mixture of the metal and the white oxide.

Arsenic decomposes many of the Salts.— The nitrates detonate with arsenic, convert it into arsenic acid, and this combining with the base of the nitrate, forms an arseniate that remains at the bottom of the vessel.

If three parts of chlorate of potassa be mixed with one part of arsenic in fine powder, which must be done with great caution and with a light hand, a small quantity of this mixture, placed on an anvil, and struck with a hammer, will explode with flame and a considerable report ; if touched with fire, it will burn with considerable rapidity ; and if thrown into concentrated sulphuric acid, at the moment of contact a flame rises into the air like a flash of lightning, which is so bright as to dazzle the eye.—*Ure's Chem. Dict.*

NATIVE STATE AND PREPARATION. Metallic arsenic sometimes occurs native, but more frequently it is found in combination with other metals, and especially with cobalt and iron. From the oxide obtained
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by roasting these ores, the pure metal may be procured by mixing it with oil and subliming at a low red heat in a clean Florence flask, or by mixing it with about twice its weight of black flux, [prepared by detonating, in a crucible, one part of nitre with two of crystals of tartar,] and exposing the mixture to a red heat, in an Hessian crucible, over which is luted an empty crucible for receiving the metal.

ARSENIC AND OXYGEN.

Chemists are acquainted with two compounds of these substances, and as they both possess acid properties, the terms *Arsenious* and *Arsenic* acid have been properly applied to them. There is, however, some difference of opinion concerning their composition. I shall adopt the views of Berzelius with regard to them, as probably, the most correct.

Arsenious Acid.—Atom. Num. 49.7—*Symb.* $1\frac{1}{2}$ O+As.

SYN.　*White Oxide of Arsenic.— White Arsenic.*

PROPERTIES. A semi-transparent, white and brittle substance, of a sweetish taste; its specific gravity is 3.7; is volatilized at $380°$ F. yielding vapours, which do not possess the odour of garlic, and which condense unchanged on cold surfaces; but if suddenly heated it runs into a transparent brittle glass; it is sparingly soluble in water, and more so in hot than in cold; it reddens vegetable blue colours, and combines with salifiable bases forming salts, which are termed *Arsenites.*

Taste of Arsenious acid.—The taste of this substance is generally thought to be acrid; but Dr. Christison states that from personal observation he is satisfied that it may be deliberately tasted without exciting more than a very faint impression of sweetness and perhaps of acidity. The acrid taste usually ascribed to it has probably been confounded with the local inflammation which results from its applications.

Crystallization.—By the slow sublimation of arsenious acid in a glass tube, it is always obtained in distinct octahedral crystals of an adamantine lustre, and possessing perfect transparency. It has also been found by Wohler in the form of six-sided scales, among the products of the manufacture of smalt. It separates from hot saturated solutions in small four-sided crystals which are sometimes transparent, but more frequently of a milky white.

Solubility.—According to Klaproth and Bucholz 1000 parts of boiling water dissolve 77.75 of arsenious acid; and the solution after having cooled to $60°$ F., contains only 30 parts. M. Guibourt has recently ascertained that there is a considerable difference in the solubility of the vitreous arsenious acid, and that of the same substance when it become opaque by the action of the air. Thus, 1000 parts of temperate water dissolve 12.5 parts of the opaque acid and only 9.6 of the transparent; and the same quantity of boiling water dissolves 114.7 of the opaque and 96.8 of the transparent, and retains, when cold 29.0 of the former and 17.8 of the latter.—*Dumas,* i. 355.

PREPARATION. This compound is always generated when metallic arsenic is heated in open vessels, and it may also be prepared by digesting the metal in dilute nitric acid.

ACTION ON THE ANIMAL ECONOMY.—Arsenious acid acts as a poison not only when taken into the stomach, but when applied to a wound, or when its vapour is inspired. It is the prevailing opinion of writers on this subject, that it produces its deleterious effects more from its constitutional operation than from the local inflammation which it excites. Inflammation, more or less manifest, is certainly often present, but frequently in fatal cases it is not very striking, and it is difficult to believe that this and its consequences can be the cause of the *rapid* dissolution so generally noticed from the exhibition of arsenic.

Toxicologists are somewhat divided as to the organ or part which is affected. The opinion of some is, that the action "is a consequence of the poison entering the *blood*, and so passing to the remote organs acted on," while others consider that "the organ which is remotely affected sympathizes, through the medium of the *nerves*, with the impression made on the organ which is affected primarily."

The symptoms vary with the quantity taken and the constitution of the sufferer. The earliest and most common are pain and vomiting; yet there are exceptions even to these. In cases rapidly fatal, extreme faintness, cold sweats, oppression and slight convulsions are seen. If life be prolonged beyond twenty-four hours, the vomiting and retching are often succeeded by diarrhœa, burning heat and extreme pain in the stomach and intestines—the urinary passages are in many cases affected—the pulse is very small—the countenance extremely anxious and the skin livid, or sometimes affected with eruptions. In those who survive, nervous diseases resembling convulsions, palsy or epilepsy are noticed for a length of time.

These are the leading symptons—for their variation in different cases, see *Christison on Poisons*.

It has been recently ascertained that the perhydrate of iron with the addition of a small quantity of ammonia acts as an antidote to arsenious acid. It converts the arsenious acid into an insoluble arsenite of iron. The perhydrate of iron may be obtained by precipitating the solutions of the persalts of iron by the addition of ammonia. It is totally insoluble and exerts no action on the animal economy.

TESTS.—If the poison be found in a *solid state*, it should be slowly dried on a filter. It must then be mixed with two or three parts of freshly ignited charcoal and the whole put into a glass tube, two or three inches long, blown with a small bulb at the closed end, and drawn out as in the accompanying figure.
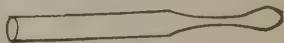
For the purpose of introducing the mixture into the tube, a small glass funnel is the best; and to it may be previously fitted a brass or silver wire, for pushing down the matter that adheres. The materials should not be too closely rammed together, and the inner part of the tube above them should be made perfectly clean and dry, which may be affected by using a small roll of filtering paper.

The apparatus being thus prepared, the flame of a spirit lamp is now carefully applied to the upper part of the material for the purpose of driving off the contained moisture, which as it collects in the upper part of the tube is removed by the filtering paper as above noticed. The flame is now
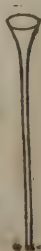
applied to the bottom of the tube, which may be held in an inclined position; and if any arsenic is present a bright metallic crust, resembling polished steel, but darker in colour, will be formed on the inside. This is metallic arsenic, and the test is called the *reduction* of the metal. When heat is cautiously applied to the crust, the metal rises in vapour, and the alliaceous odour will be perceived. Although the experiment thus far affords satisfactory evidence of the presence of arsenic, it may be further strengthened by reconverting the metal into arsenious acid. This can be done if the tube be quite clean and dry, by holding that part of it to which the arsenic adheres, about three fourth of an inch above a very small spirit-lamp flame so that the metal may be slowly sublimed. As it rises in vapour it combines with oxygen and is deposited within the tube in resplendent octahedral crystals.

If the suspected substance be in a *fluid state*, a portion of it is to be slightly acidulated with acetic acid, and after adding as much distilled water as may be necessary, subjected to a stream of sulphuretted hydrogen gas for ten or fifteen minutes. The apparatus best fitted for this purpose is here figured, the sulphuret of iron and water being introduced into the bottle so as to rise above the lower aperture of the funnel and the end of the bent tube placed in the solution. Sulphuric acid is now poured into the funnel and this acting upon the sulphuret of iron causes the extrication of sulphuretted hydrogen which passes into the solution through the bent tube. If the application of heat be found necessary for the disengagement of the gas, the bent tube and funnel may be passed through a cork and fitted into the mouth of a Florence flask or matrass.

If the solution, thus charged with sulphuretted hydrogen, is arsenical, it will assume a bright lemon yellow colour and in some cases a yellow precipitate will be thrown down, being the *Sulphuret of Arsenic*. Should the proportion of arsenious acid be small, there will only be a yellowness, owing to the sulphuret being soluble in an excess of sulphuretted hydrogen. This excess may be expelled by boiling, after which a distinct precipitate is produced.

Berzelius states that if the liquor becomes yellow without depositing sulphuret of arsenic during the evaporation, it should not be regarded as a proof of the presence of arsenic. The liquor almost always assumes this tint when it contains nitric acid, which reduced to the state of nitrous acid gives a yellow tint to the dissolved animal matters. In a recent investigation I had an opportunity of satisfying myself of the correctness of this remark. It should serve as a caution against the use of nitric acid in such cases.

The precipitate obtained by the above process is to be separated by filtration, washed, carefully dried, mixed with black flux, placed in a glass and treated as above described. On applying heat, the polished crust of metallic arsenic is formed.

To another portion of the suspected solution, a solution of nitrate of silver may be added as long as a white precipitate falls down, and after its subsidence, drop in ammonia : if arsenic be present, a beautiful

Fowlers solation
6 4 gr carb of potassa
6 4 gr ot

yellow precipitate will be produced, being *Arsenite of Silver*. This is a modification of the well known test of Dr. Marcet, and proposed by Dr. Forbes, professor of Chemistry at Aberdeen, to obviate some of the objections made to it.

To a third portion, the ammoniaco sulphate of copper, in solution, is added, when a precipitate of an apple or grass green colour is perceived being the *Arsenite of Copper*.

When the above results are obtained from any suspected substance, we need not hesitate in pronouncing it arsenic. No other presents the characteristics now described, and it should be remembered that it is their *combination* that renders the proof so unequivocal. The reduction is the most satisfactory and decisive, but even here the metal should be reoxidized, dissolved in water and treated with the liquid tests in order to meet every possible objection.

Sometimes the presence of organic matters interferes with the processes just mentioned. Their removal may often be sufficiently effected by adding acetic acid to the solution and separating the coagulated substances by filtration ; but a more complete separation may be produced by evaporating the solution at a moderate heat to dryness, redissolving anew by boiling successive portions of distilled water on the residue, and then filtering the solution after it has cooled. By this means most of the organic matters are rendered insoluble.

ADULTERATION.—Arsenious acid is liable to be mixed with chalk and sulphate of lime. If the suspected arsenic is heated in an iron spoon, it ought to volatilize. If it contains chalk and sulphate of lime, they remain behind.

REFERENCES. *On the solubility of Arsenious Acid, see a notice of the papers of Bucholz and Fisher, in Ann. of Phil. v. 29. vii. 33. Christison on the taste of Arsenic, Edin. Med. and Surg. Jour. xxviii. 95. On the Tests of Arsenic, see Christison, in Edin. Medico-Chirurgical Trans. ii. and in E in. Med. and Surg. Jour. xxii. and the Treatise on Poisons by the same author ; Forbes, in Edin. Med. and Surg. Jour. xxxii. ; R. Phillips, in Ann. of Phil. xxvi. 298. Beck's Medical Jurisprudence contains a detailed account of the tests of arsenic and copious references to authorities.*

✝ *Arsenic Acid.—Atom. Num. 57·7—Symb. 2½ O+As.*

PROPERTIES. A white concrete substance, with a sour metallic taste ; it reddens vegetable blues, and combines with bases forming salts, term ed *arseniates* ; attracts moisture from the air, and dissolves in five or six times its weight of cold, and in a still smaller quantity of hot water ; it forms irregular grains when its solution is evaporated, but does not crystallize ; when strongly heated it fuses into a glass which is deliquescent ; but when urged by a very strong red heat it is resolved into oxygen and arsenious acid : it is an active poison.

This acid may be formed by dissolving one part of arsenious acid in six parts of concentrated nitric acid, and distilling the solution to perfect dryness. It is found in nature in combination with several of the metallic oxides.

chalk and water mucilagenous.

drank.o.

ARSENIC AND CHLORINE.

Chloride of Arsenic.—Atom. Num. 90·87—*Symb.* 1½ Cl+As.

SYN. *Fuming liquor of Arsenic.—Butter of Arsenic.*

PROPERTIES. A colourless, very soluble liquid, which fumes very strongly on exposure to the air. and is resolved by water into muriatic and arsenious acids; by the aid of heat it dissolves sulphur and phosphorus, which however separate as the liquid cools.

PREPARATION. This chloride is prepared by submitting to distillation a mixture of six parts of corrosive sublimate with one of arsenic. The same compound is also formed when arsenic in powder is thrown into a jar full of dry chlorine gas.

According to Berzelius there is another chloride of arsenic, containing a less proportion of chlorine than the above; [*Traité de Chim.* ii. 411] and that prepared by the process of Dumas is perhaps also distinct from both.—*Brande's Jour. N. S.* i. 234.

ARSENIC AND BROMINE.

When arsenic is brought into contact with bromine, the two bodies unite, according to Serullas, with the disengagement of light. Arsenic is to be added in small quantities to the bromine until it ceases to produce deflagration, when the mass is to be distilled. The bromide comes over in the form of a colourless and yellowish liquid and crystallizes in the recipient.—*Berzelius*, ii. 442.

ARSENIC AND IODINE.

These two bodies unite and form a deep red compound which decomposes water, and affords arsenic and hydriodic acids. It has been made the subject of a memoir by M. Plisson.—*Ann. de Chim. et de Phys., Nov.* 1828.

Fluoride of Arsenic is a fuming. colourless liquid, which by the action of water completely decomposes glass. It has been examined by Unverdorben.—*Berzelius*, ii. 243.

ARSENIC AND HYDROGEN.

Hydruret of Arsenic, or Arseniuretted Hydrogen.—Atom. Num. 39·2—*Symb.* 1½ H+As.

Discovered by Scheele and obtained in a pure form according to Soubeirain, by fusing arsenic with its own weight of granulated zinc, and decomposing the alloy with strong muriatic acid.

PROPERTIES. A colourless gas, having a fetid odour like that of garlic; its specific gravity according to Dumas is 2·695; it extinguishes bodies in combustion, but is itself kindled by them, and burns with a blue flame; it instantly destroys small animals that are immersed in it, and is poisonous in a .high degree, having proved fatal to a German philosopher, M. Gehlen; water absorbs one-fifth of its volume, and ac-

quires the odour of the gas; it does not possess acid properties; it is decomposed by various agents, as heat, atmospheric air, chlorine and iodine, and with oxygen it forms an explosive mixture.

Gay Lussac has also described a solid compound of arsenic and hydrogen, separating in the form of chestnut brown coloured flocks, during the action of water upon an alloy of potassium and arsenic. Its composition is unknown.— *Thenard, Traité de Chim.*

ARSENIC AND SULPHUR.

Chemists differ as to the number of definite compounds formed by these bodies. Some assert that there are but two; others that there are three, while Berzelius, in his treatise, describes no less than five. I shall adopt the view of these compounds contained in Dr. Turner's elements.

Protosulphuret of Arsenic.—Atom. Num. 53·7—*Symb.* S+As.

Syn. *Sulfide Hyparsenieux.*—Berzelius.

This sulphuret occurs native, and is known in mineralogy by the name of *Realgar.* It may be formed artificially by heating arsenious acid with about half its weight of sulphur, until the mixture is brought into a state of perfect fusion. The cooled mass is crystalline, transparent, and of a ruby red colour; and may be sublimed in close vessels without change.

Sesquisulphuret of Arsenic.—Atom. Num. 61·7—*Symb.* 1½ S+As.

Syn. *Sulfide Arsenieux.*—Berzelius.

Occurs in nature, and known by the name of *Orpiment.* Formed artificially by fusing together equal parts of arsenious acid and sulphur; or better, by transmitting a current of sulphuretted hydrogen gas through a solution of arsenious acid.

Properties. This compound has a rich yellow colour; it fuses readily when heated, and becomes crystalline on cooling, and in close vessels may be sublimed without change. It is dissolved with great facility by the pure alkalies, and yields colourless solutions.

Uses. Orpiment is employed as a pigment, and is the colouring principle of the paint called *King's Yellow.* M. Braconnot has proposed it likewise for dying silk, woollen, or cotton stuffs of a yellow colour. For this purpose the cloth is soaked in a solution of orpiment in ammonia, and then suspended in a warm apartment. The alkali evaporates, and leaves the orpiment permanently attached to the fibres of the cloth.—*Ann. de Chim. et de Phys.* xii. *or Brande's Jour.* ix. 184.

Persulphuret of Arsenic.—Atom. Num. 77·7—*Symb.* 2½ S+As.

This sulphuret has a colour very similar to orpiment; it is dissolved by pure alkalies, fuses by heat, and may be sublimed in close vessels without decomposition.

It is prepared by transmitting sulphuretted hydrogen gas through a moderately strong solution of arsenic acid; or by saturating a solution

of arseniate of potassa or soda with the same gas, and acidulating with muriatic or acetic acid. The oxygen of the acid combines with the hydrogen of the gas, and the persulphuret of arsenic subsides.

The experiments of Orfila have proved that the sulphurets of arsenic are poisonous, though in a much less degree than arsenious acid. The precipitated sulphuret is more injurious than the native orpiment.

ARSENIC AND THE METALS.

Arsenic combines with most of the metals, which it generally renders brittle, even though in very small quantity. Many of these alloys are found in nature, and are known by the name of *Arseniurets.*

The alloy of three parts of tin and one part of arsenic, is white, very brilliant and brittle; it crystallizes in large plates, is more fusible than arsenic, but less so than tin. It is employed in the laboratory in the preparation of arseniuretted hydrogen, and is formed by heating a mixture of three parts of tin and two of arsenic in a covered crucible. The alloy of copper and arsenic is white, and so very similar in its appearance to silver, as to be substituted for it.

ARSENIOUS ACID AND SALIFIABLE BASES.

These compounds, termed *Arsenites,* have not been much examined. The *Arsenites of Potassa, Soda* and *Ammonia,* are soluble and incapable of crystallizing; and they may be easily prepared by boiling a solution of these alkalies in arsenious acid. The other arsenites are insoluble, or, at most, sparingly soluble in pure water; but they are dissolved by an excess of their own acid, with great facility by nitric acid, and by most other acids with which their bases do not form insoluble compounds. The insoluble arsenites are easily formed by the way of double decomposition.

On exposing the arsenites to heat in close vessels, either the arsenious acid is dissipated in vapour, or they are converted, with disengagement of some metallic arsenic, into arseniates. Heated with charcoal or black flux, the acid is reduced with facility.

The soluble arsenites, if quite neutral, are characterized by forming a yellow *Arsenite of Silver* when mixed with the nitrate of that base, and a green *Arsenite of Copper, Scheele's green,* with sulphate of copper. When acidulated with acetic or muriatic acid, sulphuretted hydrogen causes the formation of orpiment. The insoluble arsenites are all decomposed when boiled in a solution of carbonate of potassa or soda. *German green* and *Schweinfurt green,* are mixtures of the arsenite and acetate of copper.

The *Arsenite of Potassa* is the active ingredient in the *Liquor Potassæ Arsenitis* of the *U. S. Pharmacopœia* and in *Fowler's mineral solution* or *tasteless ague drop.*

ARSENIC ACID AND SALIFIABLE BASES.

These compounds, termed *Arseniates,* resemble the phosphates in this as in other respects, that though carefully neutralized when in solution, yet when concentrated by evaporation, they crystallize with an excess of base.

Arseniate of Ammonia is formed by saturating arsenic acid with ammonia ; rhomboidal prisms are obtained on evaporation, which, when gently heated, effloresce and evolve ammonia.

Biarseniate of Potassa.—This salt occurs in four-sided rectangular prisms, terminated by very short four-sided pyramids ; is permanent in the air and has a saline cooling taste ; is soluble in about five times its weight of cold water, but is insoluble in alcohol.

It may be formed by adding excess of arsenic acid to potassa, or by distilling in a retort equal weights of nitre and arsenious acid.

Arseniate of Soda forms large crystals, having the same shape as phosphate of soda, which effloresce by exposure to a dry atmosphere ; it has a cooling taste, resembling that of carbonate of soda, but less strong : is soluble in about four times its weight of cold water, and the liquid has alkaline properties ; it undergoes watery fusion ; its solution when dropped into most earthy and metallic salts, occasions precipitates, the peculiar appearances of which, are exhibited by Dr. Thomson, in a table published in the *Ann. of Phil.* xv. 83.

Arseniates of Lime.—According to Mr. Dalton lime and arsenic acid combine in several proportions, forming an insoluble, a soluble and a neutral arseniate.

Arseniate of Baryta.—An insoluble salt, formed by mixing neutral arseniate of soda with nitrate of baryta.

Arseniates of Iron.—There are three native arseniates of iron, exactly similar in their composition to the analogous phosphates of iron.

Arseniate of Zinc, is precipitated in the form of a white insoluble powder when arsenic acid or an alkaline arseniate is added to sulphate of zinc.

Arseniate of Tin.—Is a white insoluble powder, precipitated by adding arseniate of potassa to muriate of tin.

Arseniate of Copper, is formed by adding an alkaline arseniate to nitrate of copper. It is a blue insoluble powder.—*See Chereniz in Phil. Trans. for* 1801.

Arseniate of Lead.—This salt occurs native in the form of crystals, in Saxony and in Cornwall, Eng. It may be formed artificially by pouring arsenic acid into any of the soluble salts of lead, when it falls in the form of a white powder, insoluble in water, but soluble in dilute nitric acid, by which means we can separate it, in analysis, from sulphate of lead.

REFERENCES. *Chereniz, in Phil. Trans. for* 1801. *Thomson on Arsenic and the Arseniates, Ann. of Phil.* xv. 81. *Thenard, Traté de Chim.*

SECTION XXII.

MOLYBDENUM.

Atom. Num. 47·7.—*Symb. Mo.*—*Sp. gr.* 8·625.

Discovered by Scheele in 1778, but hitherto has been obtained only in small quantities, and is known imperfectly.
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PROPERTIES. A brittle metal of a yellowish white colour and very infusible; it has a specific gravity of 8·615, to 8·636 according to Bucholz; when heated to a dull red in open vessels, it is converted into an oxide, and at a still higher temperature it is converted into an acid.

EXTRACTION. When the native sulphuret of molybdenum, in fine powder, is digested in nitro-muriatic acid until the ore is completely decomposed, and the residue is briskly heated in order to expel sulphuric acid, molybdic acid remains in the form of a white heavy powder. From this acid metallic molybdenum may be obtained by exposing it with charcoal to the strongest heat of a smith's forge; or by conducting over it a current of hydrogen gas, while strongly heated in a tube of porcelain.—*Berzelius.*

MOLYBDENUM AND OXYGEN.

According to Berzelius there are three compounds of molybdenum and oxygen, viz. two oxides and an acid.

Protoxide of Molybdenum.—Atom. Num. 55·7—*Symb.* O+Mo.

A dark coloured compound, which forms salts with acids, and when heated in the open air is converted into the deutoxide. It is prepared by adding muriatic acid to the solution of a molybdate, and digesting with distilled zinc. For details, see *Berzelius,* ii. 470.

Deutoxide of Molybdenum.—Atom. Num. 63·7—*Symb.* 2O+Mo.

This oxide may be obtained in the form of a hydrate, by digesting a mixture of molybdic acid, metallic molybdenum, and sulphuric or muriatic acid, till the colour of the liquid becomes a deep red. When this liquid is treated with ammonia, a rust-yellow *hydrated deutoxide* is precipitated, which dissolves in acids and yields salts whose solutions are red, but become black, when evaporated to dryness.—*Berzelius,* ii. 473.

Molybdic Acid.—Atom. Num. 71·7—*Symb.* 3O+Mo.

A white powder, of the specific gravity of 3·4; it has a sharp metallic taste; reddens litmus paper; is very sparingly soluble in water, forms salts with salifiable bases, but as Berzelius observes, it performs the part of a base towards the stronger acids.

MOLYBDENUM AND FLUORINE.

Fluomolybdic Acid.—This acid, which was first examined by Berzelius in 1824, may be obtained by dissolving molybdic acid in fluoric acid. It has an acid, metallic and disagreeable taste, combines with bases and forms *Fluomolybdates.* It is supposed to consist of one atom fluoric acid+one atom molybdic acid.—*Thomson, Inorg. Chem.* ii. 202.

MOLYBDENUM AND CHLORINE.

With chlorine molybdenum combines in three proportions, forming compounds equivalent to its three oxides. The first is red and a little volatile. The second is black, very fusible, very volatile, and crystallizes in a black mass, of a brilliant colour like iodine, which it resembles also in the colour of its gas. The third is colourless and crystallizes in scales.—*Berzelius.*

MOLYBDENUM AND SULPHUR.

Bisulphuret of Molybdenum.—Atom. Num. 79·7—*Symb.* 2S+Mo.

A sectile compound of a metallic lustre, found native, and prepared artificially by heating one part of molybdic acid with five parts of sulphur.

The native mineral resembles graphite or plumbago, and was formerly confounded with it. It occurs exclusively in primitive rocks, and is found in various parts of the United States. These two minerals may be very well distinguished by the streak on white china; that of plumbago is grayish black,—that of sulphuret of molybdenum has an olive green tinge.— *Cleaveland's Mineralogy.*

Berzelius also describes another sulphuret of this metal, consisting of one proportion of the metal and three proportions of sulphur. It is of a ruby colour, transparent and crystallized.— *Traité de Chim.* ii. 482.

MOLYBDIC ACID AND SALIFIABLE BASES.

The *Molybdates* appear to be numerous, but they have not been attentively examined. According to Dr. Thomson the molybdates of potassa, soda, ammonia, lime, magnesia, cobalt and rhodium are soluble in water. The other molybdates mentioned in his table are insoluble or nearly so. [*First Prin.* ii. 60.] These salts may be procured in a manner similar to the analogous compounds of chromic acid. *Molybdate of Lead* is found native, principally in crystals of different shades of yellow.

REFERENCES. *For further information concerning this metal and its compounds, see Scheele's Chem. Essays, the elaborate experiments of Bucholz, in Gehlen's Jour.* iv. 618, *or Repert. of Arts,* 2d ser. x. 373, 433 ; *and the notices of its Alloys and Amalgams, from Crell's Annals, in Thomson's Chemistry.*

SECTION XXIII.

CHROMIUM.

Atom. Num. 28.—Symb. Cr.—Sp. gr. 5·3.

Chromium* was discovered in the year 1797, by Vauquelin in a beautiful red mineral, the native chromate of lead.   It has since been detected in the mineral called *Chromate of Iron*, which occurs abundantly in several parts of Europe and America.

PROPERTIES.   This metal is of a white colour, with a shade of yellow, and has a distinct metallic lustre ; it is brittle, very infusible, and with difficulty attacked by acids, even by the nitro-muriatic ; its specific gravity has been stated at 5·9 ; but Dr. Thomson found it a little above 5 ; when fused with nitre, it is oxidized, and converted into chromic acid.

PREPARATION.   Chromium, which has hitherto been procured in very small quantity, owing to its powerful attraction for oxygen, may be obtained by exposing the oxide of chromium, mixed with charcoal, to the most intense heat of a smith's forge.

REFERENCES.   *Vauquelin on Chrome, Ann. de Chim.* xxv. *or Tilloch's Phil. Mag.* i. 279, 361.   *An elaborate Memoir on Chromium and its compounds, by Dr. Thomson, in the Phil. Trans. for* 1827, *noticed in Phil. Mag. and Ann.* i. 452.

CHROMIUM AND OXYGEN.

Chromium and oxygen combine in two proportions, forming the green oxide, and chromic acid.

Protoxide of Chromium.—Atom. Num. 40*—Symb.* 1½ O+Cr.

PROPERTIES.   A substance of a green colour, exceedingly infusible and suffering no change by heat ; it is insoluble in water, and after being strongly heated, resists the action of the most powerful acids ; deflagrated with nitre, it is oxidized to its maximum, and is thus converted into chromic acid ; fused with borax or vitreous substances, it communicates to them a beautiful green colour, a property which affords an excellent test of its presence, and renders it exceedingly useful in the arts ; it unites with acids and forms salts which have a green colour.

PREPARATION AND NATIVE STATE.   This compound is found native in France, in the form of a green incrustation.   It is the colouring matter of the emerald, and exists in a few other minerals.   It is easily obtained by calcining to redness chromic acid or the chromate of mercury ; the mercury is volatilized with a part of the oxygen, while the protoxide remains.

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* So called from the Greek, *chroma, colour*, in allusion to its property of forming coloured salts.

Brown Oxide.—A brown compound of chromium and oxygen, was first noticed by Vauquelin, and has since been supposed, by some chemists, to be a *deutoxide*, by others, to be *chromous acid*. It is prepared by passing a current of sulphurous acid gas through a solution of chromate or bichromate of potassa, and washing and drying the precipitate. According to Dr. Thomson it is nothing more than a compound of one atom of chromic acid and six atoms of green oxide, and is incapable of forming peculiar compounds. [*Phil. Trans.* 1827.] This view is, in the main, confirmed by the experiments of Maus.—*Ann. de Chim. et de Phys.* xxxv. 216. *See also Berzelius,* ii. 456.

Chromic Acid.—Atom. Num. 52—*Symb.* 3O+Cr.

PROPERTIES. Chromic acid has a dark ruby-red colour, and forms irregular crystals when its solution is concentrated ; it is very soluble in water, has a sour taste, and possesses all the properties of an acid ; is converted into the green oxide, with evolution of oxygen, by exposure to a strong heat ; it yields a muriate of the protoxide, when boiled with muriatic acid and alcohol, and the direct solar rays have a similar effect when muriatic acid is present. With sulphurous acid, it forms a sulphate of the protoxide; it is characterized by its colour, and by forming coloured salts with bases, the most important of which is chromate of lead.

PREPARATION. This acid may be prepared by digesting chromate of baryta in a quantity of dilute sulphuric acid exactly sufficient for combining with the baryta. The sulphate of baryta subsides, and a solution of chromic acid is obtained. Dr. Thomson proposes another method of preparing this acid by acting on the green oxide with nitric acid ; and Maus obtains it by decomposing a hot and concentrated solution of bichromate of potassa with fluosilisic acid; filtering the liquid and evaporating to dryness in a platinum capsule. The acid thus dried is then dissolved in the smallest possible quantity of water, to exclude a portion of fluosilicate of potassa, which has passed the filter, and the fluid decanted ; for in this state of concentration, chromic acid cannot be filtered, as it attacks paper and is converted into oxide of chromium.—*Brande's Jour. N. S.* iii. 488.

CHROMIUM AND CHLORINE.

Chlorochromic Acid Gas, or Chloride of Chromium.

Discovered by M. Unverdorben, in 1825.

PROPERTIES. A red coloured gas, which may be collected in glass vessels over mercury ; it is instantly decomposed by water, and yields a solution of muriatic and chromic acids; it may be regarded either as a compound of muriatic and chromic acids, or of chlorine and chromium. M. Walter calls it the bichromate or perchloride of chrome, or chloro-oxi-chromic acid.—*Lond. and Edin. Phil. Mag. &c.* xii. 83.

Wohler states that when the chloride of chromium is passed in a state of vapour, through a glas tube heated to redness, it is decomposed into an oxide of chromium and a mixture of chlorine and oxygen gases. The former remains in the tube in the form of black shining crystals which are as hard as corundum.

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This compound is formed by the action of fuming sulphuric acid or a mixture of chromate of lead and chloride of sodium.— *Edin. Jour. of Science*, iv. 129.

Dr. Thomson has also described a red coloured liquid under the name of *Chlorochromic Acid*, which he obtained by the action of concentrated sulphuric acid on the mixture of dry bichromate of potassa and sea-salt. He supposes it to consist of one atom of chromic acid and one of chlorine, but there are still some doubts with regard to its composition.— *Thomson, in Phil. Trans. for* 1827, *and Inorg. Chem.*

CHROMIUM AND FLUORINE.

Fluochromic Acid Gas, or Fluoride of Chromium.

PROPERTIES. A gaseous substance, acting rapidly upon glass with the deposition of chromic acid, and the formation of fluosilisic acid gas; it is absorbed by water, and the solution is found to contain a mixture of hydrofluoric and chromic acids; it is decomposed by the watery vapour of the atmosphere, so that when mixed with air, red fumes appear, owing to the separation of minute crystals of chromic acid.

This gas was first obtained by M. Unverdorben, by distilling a mixture of fluor spar and chromate of lead with fuming or even common sulphuric acid, in a leaden retort. It may be collected and kept for a short time in glass vessels coated with resin.—*Berzelius.*

Sulphuret of Chromium.—A dark gray compound, without the metallic lustre; formed by passing the vapour of sulphuret of carbon over the oxide of chromium heated to redness in a porcelain tube.—*Berzelius*, ii. 463.

Phosphuret of Chromium.—A grayish mass, obtained by subjecting phosphate of chromium to heat in a forge.— *Berzelius*, ii. 465.

CHROMIC ACID AND SALIFIABLE BASES.

The compounds termed *Chromates*, are mostly of a red or yellow colour, and on being boiled in muriatic acid mixed with alcohol, the chromic acid is at first set free and is then decomposed, a green muriate of the oxide of chromium being generated.

Chromate of Potassa.—Atom. Num. 99·15—*Symb.* (3O+Cr. (O+Po.)

PROPERTIES. An anhydrous salt, having a cool bitter, and disagreeable taste; it forms crystals, the primary shape of which is a right rhombic prism, [*Ann. of Phil.* xxii. 120,] and is of an intense lemon yellow colour, with a slight shade of orange; is soluble to a great extent in boiling water, and in twice its weight of the liquid at 60° F.; is insoluble in alcohol; has an alkaline reaction, from which it has been incorrectly supposed to be a sub-salt; its solution in water decomposes most of the metallic salts, furnishing some valuable pigments.

Action of Carbon.—Neutral chromate of potassa may be exposed to a very high temperature without being decomposed, unless charcoal

be added to it, which renders it incandescent. Hemp, cotton, linen or cloth impregnated with this salt become very combustible and burn with a strong, a very lively incandescence and with considerable disengagement of light and heat. The oxides of chromium and its different salts possess the same property.—*Jacobson, Jour. de Chim.*

PREPARATION. This salt, from which all the compounds of chromium are directly or indirectly prepared, is made by heating to redness the native oxide of chromium and iron, commonly called *Chromate of Iron*, with an equal weight of nitrate of potassa, when chromic acid is generated, and unites with the alkali of the nitre. After digesting the ignited mass in water until the chromate is dissolved, the solution is neutralized by nitric acid, and concentrated by evaporation, in order that the nitrate of potassa should crystallize. The residual liquid is then set aside to evaporate spontaneously, and the chromate is gradually deposited in small prismatic crystals.

Bichromate of Potassa.—*Atom. Num.* 151·15—*Symb.* 2(3O+Cr.)+ (O+Po.)

This salt occurs in four-sided tabular crystals, the primary form of which is an oblique rhombic prism; it is of an exceedingly rich red colour, is soluble in about ten times its weight of water at 60° F. and the solution reddens litmus paper.

Bichromate of potassa is made by acidulating the chromate with sulphuric acid, and allowing the solution to crystallize by spontaneous evaporation. It is used in dying.

Chromate of Iron is found native in Siberia, France and the United States, in small crystalline grains, of an octahedral form; but it more commonly occurs massive, of a black colour, with a slight metallic lustre, and hard enough to scratch glass.

Chromate of Lead.—*Atom. Num.* 163·5— *Symb.* (3O+Cr.)+(O+Pb.)

This is a very rare mineral found only in Siberia. It is prepared artificially by adding chromate of potassa to a soluble salt of lead. It is of a fine yellow, and is known in commerce by the name of *Chrome Yellow.*

Dichromate of Lead.—*Atom. Num.* 275.— *Symb.* (3O+Cr.)+(2O+Pb.)

A salt, called also the *Subchromate of Lead*, of a beautiful red colour, formed by boiling carbonate of lead with excess of chromate of potassa. It is recommended by Mr. Badams as a pigment.—*Ann. of Phil.* xxv. 303.

Besides the above there are chromates of ammonia, soda, lime and magnesia, which are soluble and crystallizable; chromates of baryta and strontia, which are difficultly soluble; and those of silver, mercury, copper and uranium, the colours of which are crimson, red, apple-green and yellow. The insoluble chromates are formed by mixing soluble salts of those bases, with chromate of potassa or soda.

REFERENCES. *For further details concerning the compounds of Chromic Acid with bases, see Vauquelin, Ann. de Chim.* lxx. *Dr. John, on*

some unknown combinations of Chromic Acid, Ann. of Phil. iv. 424 ; *Dr. Thomson, in the same work,* xvi. 321 ; *Grouvelle, Ann. de Chim. et de Phys.* xvii. ; *and Stokes, on some new double Chromates, Phil. Mag. and Ann.* ii. 427. *On the Poisonous properties of the Chromates, see Christison on Poisons,* 372 ; *and Dr. Duncan, in the Edin. Med. and Surg. Jour.* xxvi. 133.

SECTION XXIV.

VANADIUM.

Atom. Num. 68·5.— *Symb.* V.

VANADIUM, so called from *Vanadis,* the name of a Scandanavian divinity, was discovered by Sefstrom in 1830, in the iron from the forges of Eckersholm in Sweden; and in 1831 it was found in an ore of lead from Wanlock Head, by Mr. Johnston of Edinburgh.[*] It has been obtained by heating vanadic acid in contact with potassium and by the decomposition of the chloride of vanadium.

PROPERTIES. This metal as obtained by means of potassium, is a heavy black powder, with very little lustre. But when prepared by the decomposition of the chloride, it has a white colour resembling silver, a strong metallic lustre, but it is extremely brittle. It is not oxidized by either air or water, is not acted on by boiling sulphuric, muriatic, or hydrofluoric acid, but is attacked by the nitric and nitro-muriatic acids, and the solution has a fine dark blue colour.

VANADIUM AND OXYGEN.

Vanadium combines with oxygen in three proportions.

Protoxide of Vanadium.—Atom. Num. 76·5—*Symb.* O+V.

A dark brown or black compound, soluble in nitric acid and in aqua regia, but does not form salts. It is obtained by reducing vanadic acid by hydrogen gas.

Deut or Binoxide of Vanadium.—Atom. Num. 84·5—*Symb.* 2O+V.

A black and pulverulent substance, very infusible and insoluble in water ; heated in the air it attracts oxygen and is converted into vanadic acid ; forms salts with the acids, which when anhydrous are dark-brown, and when they contain water, of a deep blue like the salts of copper ; it also combines with alkalies, forming brown soluble compounds.

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[*] According to Humboldt it appears that this metal had been discovered in Mexico, by M. del Rio, in a brown lead ore, found in the district of Zimampas. M. del Rio gave it the name of *Erythronium,* but was afterwards induced to suppose it merely an impure chrome. Since the discovery of Sefstrom, however, the brown lead ore of Zimampas has again been analyzed, and a simple substance, precisely similar to that found in the iron by Sefstrom, obtained from it.—*Jour. of Royal Institution,* ii. 562.

Vanadic Acid.—Atom. Num. 92·5*—Symb.* 3O+V.

PROPERTIES. This compound is a yellow powder, tasteless, sparing-ly soluble in alcohol and water, to which liquid it imparts a yellow co-lour ; fuses at a red heat and on cooling crystallizes in beautiful pris-matic crystals, transparent at the edges, of a reddish brown colour and a high degree of lustre; it forms with bases neutral salts which in general are colourless, and acid salts of a bright orange colour ; gives also saline combinations with the acids ; may be distinguished from all other acids except the chromic by its colour and from this by the ac-tion of deoxidizing substances, which give a blue solution with the for-mer and a green with the latter.

Vanadic Acid forms colourless as well as coloured Salts.—One of the most singular facts with regard to this acid is that its *neutral salts* are yellow at one time and colourless at another without suffering any ap-preciable change in composition.   Thus on neutralizing vanadic acid with ammonia a yellow salt is obtained, the solution of which gradu-ally becomes colourless if kept for some hours, and suffers the same change rapidly when heated.   The solution, as it is coloured or colour-less, gives a white residue by evaporation, and a yellow or white pre-cipitate with a salt of lead or baryta.*

PREPARATION. By heating the vanadiate of ammonia in an open vessel and well stirred, the whole mass acquires a dark red colour, and pure vanadic acid is obtained ; but a red heat should be avoided, since fusion would thereby be occasioned, and free exposure of every part to the atmosphere prevented.

VANADIUM AND CHLORINE.

Bichloride of Vanadium—is prepared by digesting a mixture of the vanadic and muriatic acids, deoxidizing any undecomposed vanadic acid by sulphuretted hydrogen and evaporating the solution to dryness. A brown residue is obtained, which yields a blue solution with water, part being left as an insoluble sub-salt. It may also be generated by acting directly on the ignited deutoxide with strong muriatic acid.   As thus obtained its solution is brown instead of blue, though in composi-tion it seems identical with the preceding.— *Turner.*

The *ter-Chloride* may be formed by transmitting a current of dry chlorine gas over a mixture of protoxide of vanadium and charcoal heated to low redness, when the terchloride passes over in vapour, and condenses in the form of a yellow liquid, from which free chlorine may be removed by a current of dry air.   It is converted by water into mu-riatic and vanadic acid, and atmospheric moisture produces the same change indicated by the escape of red fumes.— *Turner.*

* A new and almost indelible ink, is prepared by Berzelius from vanadium. It is formed by mixing the vanadiate of ammonia with infusion of galls ; a black liquid is produced which is the best writing ink that can be formed. Acids render it blue but do not obliterate it ; the alkalies when sufficiently diluted not to act upon the paper do not dissolve it, and chlorine which destroys the black colour does not, however, efface the writing even when water is after-wards suffered to run over it.—*Phil. Mag. and Ann. N. S.* xi. 16.

Compounds of vanadium and bromine, iodine, fluorine and cyanogen, may be formed by dissolving deutoxide of vanadium in hydrobromic, hydriodic, hydrofluoric and prussic acids.

VANADIUM AND SULPHUR.

Bisulphuret of Vanadium—is a compound of a brown colour which becomes black when it is dried and which takes fire when heated. It is obtained by heating the deutoxide of vanadium to redness in a current of sulphuretted hydrogen, or by mixing with a salt of the deutoxide of vanadium a hydrosulphuretted alkali until the precipitate at first formed is re-dissolved, and then decomposing the deep purple-coloured solution by sulphuric or muriatic acid.

Ter-sulphuret of Vanadium—is formed by acidulating a solution of vanadic acid in a hydrosulphuretted alkali by muriatic or sulphuric acid. It has a much lighter brown colour than the bisulphuret, becomes almost black in drying, and is resolved by a red heat in close vessels into the bisulphuret with loss of water and sulphur. It is soluble in alkalies and alkaline hydrosulphates, and is oxidized by nitric acid.

VANADIUM AND PHOSPHORUS.

Phosphuret of Vanadium—is of a leaden-gray colour, and may be formed by exposing to a white heat phosphate of deutoxide of vanadium mixed with a small quantity of sugar.

REFERENCES. *Berzelius on Vanadium, Phil. Mag. and Ann.* x. 321. xi. 7. *Johnston in Brewester's Jour. N. S.* v. 318. *Reports of the British Association for* 1832. *Turner's Chemistry,* 4th ed.

SECTION XXV.

TUNGSTEN.

Atom. Num. 99·7.—*Symb.* Tu.—*Sp. gr.* 17·4.

PROPERTIES. Colour grayish-white, like that of iron, with considerable lustre ; it is brittle, nearly as hard as steel, and less fusible than manganese ; it is surpassed in density only by gold and platinum ; it is oxidized by the action of heat and air.

This metal is obtained by exposing tungstic acid to the action of charcoal, or dry hydrogen gas, at a red heat.

TUNGSTEN AND OXYGEN.

Chemists are acquainted with two compounds of this metal and oxygen, viz : an oxide and an acid.

Oxide of Tungsten.—Atom. Num. 115·7—Symb. 2O+Tu.

PROPERTIES. A compound of a brown or nearly black colour, depending upon the mode of its preparation, which does not so far as is known, unite with acids, and which, when heated to near redness, takes fire and yields tungstic acid ; it combines, according to Wohler, with soda.—*Berzelius*, ii. 486.

PREPARATION. This oxide may be formed by the action of hydrogen gas on tungstic acid, at a low red heat. But the most convenient process is that described by Wohler. A mixture of powdered wolfram and carbonate of potassa is fused ; the resulting tungstate of potassa is dissolved in water, and a sufficient quantity of muriate of ammonia then added. The liquor is evaporated to dryness, and the mass is fused in a Hessian crucible, till the muriate of ammonia is entirely decomposed and evaporated. By dissolving the fluid mass in water, a black powder separates, which is oxide of tungsten. This is boiled with a weak solution of potassa, to remove a small quantity of acid and difficultly soluble tungstate of potassa, and then washed with abundance of distilled water.—*Ann. de Chim. et de Phys.* xxix. *Brande's Jour.* xx. 177.

Tungstic Acid.—Atom. Num. 123·7—Symb. 3O+Tu.

PROPERTIES. Tungstic acid is of a yellow colour, is insoluble in water, and has no action on litmus paper ; it forms salts with alkaline bases, called *Tungstates*, which are decomposed by the stronger acids, the tungstic acid in general falling, combined with the acid by which it is precipitated ; it has a specific gravity of 6·12 ; is difficultly fusible ; calcined in contact with air, its yellow colour becomes deeper and passes to a green, and after some hours to a gray.

NATIVE STATE AND PREPARATION. This acid has only been found in nature, combined with bases, in two rare minerals, the tungstate of lime, and the tungstate of iron and manganese, or *Wolfram.* It is artificially procured by burning in open vessels the oxide above described, or by digesting native tungstate of lime, very finely levigated, in nitric acid ; by which means the nitrate of lime is formed, and the tungstic acid separates in the form of a yellow powder. This is freed from impurities by washing it alternately with ammonia and nitric acid.—*See Berzelius*, ii. 487.

TUNGSTEN AND CHLORINE.

According to Wohler, these substances combine in three proportions.

Deutochloride of Tungsten.—A compound, of a deep red colour, which sublimes in delicate needles. It is very fusible, enters into ebullition at a slightly elevated temperature, and is converted into a red gas, of a more intense colour than nitrous acid gas. It is obtained by heating metallic tungsten in a current of chlorine gas.

Perchloride of Tungsten.—This chloride is generated by heating the oxide of tungsten in chlorine gas. The action is attended with the appearance of combustion, dense fumes arise, and a thick sublimate is

obtained in the form of white scales, like native boracic acid. It is volatile at a low temperature without previous fusion. It is converted by the action of water into tungstic and muriatic acids, and must, therefore, in composition, be proportional to tungstic acid.

Wöhler has described another chloride which is formed at the same time as the last; and though it is converted into muriatic and tungstic acids by the action of water, and would thus seem identical with the perchloride in the proportion of its elements, its other properties are nevertheless different. It is the most beautiful of all these compounds, existing in long transparent crystals, of a fine red colour. It is very fusible and volatile, and its vapour is red, like that of nitrous acid. The difference between this compound and the chloride first described, has not yet been discovered.

In addition to the above compounds, Berzelius describes a *Fluoride of Tungsten*, or *Fluo-tungstic acid*, and two *Sulphurets of Tungsten.— Traité de Chim.* ii. 489, 492.

REFERENCES. *Berzelius on Tungsten and some of its compounds, Ann. of Phil.* iii. 244. *Bucholz's experiments on Tungsten and its combinations with Oxygen, Ammonia and other substances, Ann. of Phil.* vi. 198. *Thomson's First Prin.* ii. 62.

SECTION XXVI.

ANTIMONY.

Atom. Num. 64·6.—*Symb.* Sb*—*Sp. gr.* 6·7.

The date of the discovery of this metal is unknown; but the manner of obtaining it was first described by Basil Valentine, in the fifteenth century, in a work entitled *Currus Triumphalis Antimonii.*—It was called *Regulus of Antimony.*

PROPERTIES. A brittle metal, of a silvery white colour, scaly texture, and possessing considerable lustre; it fuses at 810° F. and when slowly cooled, sometimes crystallizes in octahedral or dodecahedral crystals; in close vessels it may be volatilized and collected unchanged, but not, Thenard asserts, if atmospheric air be carefully excluded, and no gaseous matter be generated during the process; it tarnishes by exposure to the atmosphere, and when placed on ignited charcoal, under a current of oxygen gas, it burns with great brilliancy, giving off an oxide in the form of a dense yellow smoke.

PREPARATION. Antimony sometimes occurs native; but its only ore which is abundant, and from which the antimony of commerce is derived, is the sulphuret. This sulphuret was long regarded as the metal itself, and was called *Antimony*, or *Crude Antimony.*

Metallic antimony may be obtained either by heating the native sulphuret in a covered crucible with half its weight of iron filings; or by mixing it with two-thirds of its weight of cream of tartar and one-

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* From the latin word *Stibium.*

third of nitre, and throwing the mixture, in small successive portions, into a red hot crucible. By the first process, the sulphur unites with iron, and in the second it is expelled in the form of sulphurous acid; while the fused antimony, which in both cases collects at the bottom of the crucible, may be drawn off and received in moulds. The antimony thus obtained is not absolutely pure; and therefore, for chemical purposes, should be procured by heating the oxide with an equal weight of cream of tartar.

ANTIMONY AND OXYGEN.

The existence of three compounds of antimony and oxygen is now generally admitted; one of these is a salifiable basis, the other two are acids.

Protoxide of Antimony.—Atom. Num. 76·6—*Symb.* 1½O+Sb.

PROPERTIES. A powder of a dirty white colour, which fuses at a red heat and forms on cooling an opaque crystalline mass; it is very volatile, and may be sublimed in close vessels by a strong heat; when heated in open vessels it absorbs oxygen and is converted into the deutoxide; it is the bases of all the salts of antimony, and forms the *Tartar Emetic* when boiled with tartrate of potassa.

PREPARATION. Oxide of antimony may be obtained by pouring muriate of antimony into water, washing the precipitate (formerly called *Powder of Algaroth*) first with a weak solution of potassa, and afterwards with water, and then drying it; or by adding to a solution of *Tartar Emetic* a solution of ammonia, and washing the precipitate with plenty of hot water. It is also formed during the combustion of metallic antimony, though not perhaps perfectly pure.

Antimonious Acid, or Deutoxide of Antimony.—Atom. Num. 80·6—*Symb.* 2O+Sb.

PROPERTIES. White; infusible; fixed in the fire; insoluble in water, and likewise in acids, after being heated to redness; combines with bases and forms salts called *Antimonites*.
This compound is prepared by dissolving metallic antimony in nitric acid and evaporating and igniting the product; or by dissolving the metal in nitro-muriatic acid, decomposing by water, washing the precipitate and calcining it in a platinum crucible.

Antimonic Acid, or Peroxide of Antimony.—Atom. Num. 84·6—*Symb.* 2½O+Sb.

This compound may be obtained by dissolving the metal in nitro-muriatic acid, from which it may be precipitated by throwing the solution into water, as it is insoluble in that fluid. When recently prepared it reddens litmus paper, and may be dissolved in water by means of muriatic or tartaric acid. As thus obtained it is a *Hydrate*, but if exposed to the temperature of 600° F., the water is driven off and the pure peroxide remains.

PROPERTIES. This compound, when pure, is of a lemon yellow
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colour ; is decomposed by exposure to a red heat ; is not soluble in acids, but combines with bases, and forms salts, termed *Antimoniates*.

REFERENCES. *On the compounds of Antimony and Oxygen, see Berzelius,* ii. 496, *and Thenard,* ii. 368, *both of whom now recognize only three ; Prout, in Ann. Jour. de Phys.* iv. *who reduces them to two.*

ANTIMONY AND CHLORINE.

Two distinct compounds of these bodies are now recognized.

Sesquichloride of Antimony.—Atom. Num. 117·7—*Symb.* 1½Cl+Sb.

PROPERTIES. At common temperatures this compound is a soft solid and hence called *Butter of Antimony ;* it is liquified by a gentle heat, and crystallizes on cooling ; it deliquesces on exposure to the air, and when mixed with water is converted into muriatic acid, and protoxide of antimony—or *Muriate of Antimony.*

It may be obtained by throwing powdered antimony into chlorine or by distilling a mixture of antimony with twice and a half its weight of corrosive sublimate.

Perchloride of Antimony.—Atom. Num. 153·22—*Symb.* 2¼Cl+Sb.

A transparent volatile liquid, which emits fumes on exposure to the air and when mixed with water is converted into muriatic acid and hydrated peroxide of antimony. It is obtained by passing dry chlorine gas over heated metallic antimony.—*Rose, in Ann. of Phil.* xxv. 416.

ANTIMONY AND SULPHUR.

The compounds of antimony and sulphur have been examined by M. H. Rose ; according to whom there are three.—*Ann. of Phil.* xxv. 419.

Sesquisulphuret of Antimony.—Atom. Num. 88·6—*Symb.* 1½S+Sb.

This sulphuret, known by the name of *Crude Antimony,* is found native of a lead gray colour, and which, though generally compact, sometimes occurs in acicular crystals or in rhombic prisms ; it may be melted in close vessels without undergoing any change, but when slowly roasted in a shallow vessel, it gradually loses sulphur and attracts oxygen, and may then be melted into a glassy substance, transparent at the edges, and called *Glass of Antimony.*

This sulphuret may be formed artificially by fusing together antimony and sulphur, or by transmitting a current of sulphuretted hydrogen gas through a solution of tartar emetic—washing and drying the precipitate. This precipitate, according to Gay Lussac and Dr. Turner, is a hydrated sesquisulphuret of antimony.

When sulphuret of antimony is boiled in a solution of potassa, a liquid is obtained, from which, as it cools, an orange-coloured matter, called *Kermes Mineral,* is deposited ; and on subsequently neutralizing

the cold solution with an acid, an additional quantity of a similar substance, the *Golden Sulphuret* of the Pharmacopeia, subsides. According to Berzelius and Rose, kermes is a hydrated sesquisulphuret, differing from the native sulphuret solely in being combined with water. —Gay Lussac, however, maintains that it contains both oxide and sulphuret of antimony.—*Ann. de Chim. et de Phys.* xlii. 88, or *Phil. Mag. and Ann.* vii. 386. *Berzelius, Traité de Chim.*

Bisulphuret of Antimony.—*Atom. Num.* 96·6—*Symb.* 2S+Sb.

This compound is formed, according to Rose, by transmitting sulphuretted hydrogen gas through a solution of the deutoxide of antimony in dilute muriatic acid.

Persulphuret of Antimony.—*Atom. Num.* 104·6—*Symb.* 2½S+Sb.

This compound is formed by the action of sulphuretted hydrogen on a solution of the peroxide, and is identical with the golden sulphuret prepared by boiling sulphuret of antimony and sulphur, in solution of potassa.

M. Rose has likewise demonstrated, that the *Red Antimony* of mineralogists, is a compound of one proportion of the protoxide, combined with two proportions of the sequisulphuret of antimony. The pharmaceutic preparations known by the terms, of *Glass, Liver*, and *Crocus* of antimony, are of a similar nature, though less definite in composition, owing to the mode by which they are prepared. They are made by roasting the native sulphuret, so as to form sulphurous acid and oxide of antimony, and then vitrifying the oxide together with the undecomposed ore, by means of a strong heat. The product will of course differ according as more or less of the sulphuret escapes oxidation during the process.—*Turner*.

ANTIMONY AND THE METALS.

Antimony may be made to combine with nearly all the metals. The most important of these alloys, is that which it forms with lead, called *Type Metal*. The composition of this alloy varies; the smallest types, Mr. Dalton finds, are cast from an alloy composed of nearly one atom of antimony to one of lead; middle sized types of a compound of one atom of antimony and two of lead; and the largest size of one atom of antimony and three of lead.—*New System*.

Antimony may also be alloyed with tin, but if its proportion in the alloy exceeds one-fourth, the tin loses its ductility.

The alloy of one part of antimony and two parts of iron deserves notice, for the singular property which it possesses of giving fire when acted on by the file.—*Thenard*, i. 644.

The alloy of antimony and gold is remarkable in being brittle when it contains only a minute proportion of antimony. According to Hatchett, gold loses its ductility by combination with 1·1920ths of its weight of antimony.

SALTS OF ANTIMONY.

Antimony is soluble in most of the acids. When heated with *Sul-phuric Acid*, the acid is decomposed; sulphurous acid is disengaged, and the antimony being converted into protoxide, a subsulphate is the product. *Nitric Acid* dissolves this metal with great vehemence; but the most convenient solvent is the nitro-muriatic acid, which acts upon the metal both in a separate state, and as it exists in the black sulphuret. *Muriatic Acid* acts on the latter compound and evolves sulphuretted hydrogen gas in abundance, and of great purity; and muriate of ammonia is also formed, and remains in solution along with the muriate of antimony.—*Berzelius, Ann. de Chim. et de Phys.* xvii. *Henry*, ii. 85.

Phosphate of Antimony—has not been examined. The medicinal preparation called *James' Powder*, was found by Dr. Pearson to consist of 57 oxide of antimony, and 43 phosphate of lime; and it has been imitated in the *Pulvis Antimonialis* of the London Pharmacopeia, which is formed by calcining the native sulphuret with hartshorn shavings. The preparation appears to be uncertain and often even almost inert, and to vary as to the state of oxidation in the antimony, containing sometimes a large proportion of the peroxide.

REFERENCES. *Pearson, in Phil. Trans.*.1791. *R. Phillips, in Ann. of Phil.* xx. 266, xxii. 187. *Webster's Brande.*

Tartarized Antimony, or *Emetic Tartar*, is a triple salt of protox-ide of antimony, potassa and tartaric acid, which will be noticed un-der the head of the *Tartrates.*

The *Antimonites* and *Antimoniates*, are, in general, soluble in water, and easily decomposable by sulphuric, nitric and muriatic acids.— Those of potassa, soda and ammonia, are obtained directly; all the others by double decomposition. Most of these compounds, when heated strongly in a platinum crucible, burn with evolution of light and heat; this is especially the case with the antimonite and antimo-niate of copper and of cobalt. Berzelius attributes this singular phe-nomenon to the more intimate union of the molecules of these com-pounds; for he observes, that, after the calcination, the antimonites and antimoniates are with difficulty acted on, even by the strongest acids. Gay Lussac, however, dissents from this opinion.

REFERENCES. *Thenard, Traité de Chim.* iii. 459. *Berzelius, in Ann. de Chim.* lxxxvi. 225. *Gay Lussac, Ann. de Chim. et de Phys.* i. 44, *and same work*, v. 158, 160. *And for further details concerning the pro-perties of these saline compounds, see Berzelius, in Ann. de Chim. et de Phys.* xvii. 16.

SECTION XXVII.

URANIUM.

Atom. Num. 217—*Symb.* U.

Discovered by Klaproth, in 1789, in a mineral of Saxony, called from its black colour, *Pitchblende*, which consists of protoxide of ura-

nium and oxide of iron. It is a rare metal, and still imperfectly known.

PROPERTIES. This metal, as prepared by Arfwedson, by conducting hydrogen gas over protoxide of uranium, heated in a glass tube, is crystalline, of a metallic lustre and reddish-brown colour; it is not changed by exposure to the air at common temperatures, but when heated in open vessels absorbs oxygen, and is re-converted into the protoxide.

PREPARATION. Metallic uranium may be obtained from the pitchblende by the following process: reduce it to powder and expose it to heat in a muffle; then digest in dilute nitro muriatic acid, and precipitate by excess of ammonia, to retain oxide of copper; collect and wash the precipitate and dry it at a heat approaching redness.

REFERENCES. *For the details of this process, see Arfwedson's paper on Uranium, in Ann of Phil. xxiii. 253. For the process of Dr. Thomson, see his First Prin. ii. 2. On Uranium and its compounds, see also the Memoir of Bucholz, in Gehlen's Jour. or Repert. of Arts, 2d ser. viii. 294.*

URANIUM AND OXYGEN.

Chemists are acquainted with two compounds of uranium and oxygen, the *Protoxide* and the *Peroxide*.

Protoxide of Uranium.—Atom. Num. 225—Symb. $O+U$.

PROPERTIES. A compound of a dark green colour, which is exceedingly infusible, and bears any temperature hitherto tried, without change; it unites with acids, forming salts of a green colour; by the action of nitric acid it is converted into a solution, which is the nitrate of the protoxide.

This oxide is obtained by decomposing the nitrate of the peroxide by heat. It is employed in the arts for giving a black colour to porcelain.

Peroxide of Uranium.—Atom. Num. 229—Symb. $1\frac{1}{2}$ $O+U$.

PROPERTIES. This oxide is of a yellow or orange colour, and performs, as was first noticed by Arfwedson, the double function of acid and base; it is precipitated from acids as a yellow hydrate by pure alkalies, fixed or volatile, but retains a portion of these bases in combination; it is thrown down as a carbonate by the carbonate of soda or ammonia, and is re-dissolved by an excess of the precipitant, a circumstance which affords an easy method of separating uranium from iron. It is employed in the arts for giving an orange colour to porcelain.

URANIUM AND SULPHUR.

Sulphuret of Uranium, may be formed according to Rose by transmitting the vapour of bisulphuret of carbon over protoxide of uranium strongly heated in a tube of porcelain. It is of a dark gray, or nearly black colour, is converted into protoxide of uranium when heated in the open air, and is readily dissolved by nitric acid.

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SALTS OF URANIUM.

It is difficult to obtain the protosalts of this metal pure, in consequence of the tendency of the protoxide to pass to the state of peroxide. The green solutions of the former, by the action of sulphuric and muriatic acids, become speedily yellowish, green and yellow, in consequence of the formation of peroxide, and the change is accelerated by adding a little nitric acid.

The *Penitrate of Uranium*, is formed by dissolving the protoxide in nitric acid, and from this solution the *Percarbonate* is thrown down by carbonate of ammonia. The pernitrate crystallizes easily, in large flat four-sided rectangular prisms, of a lemon yellow colour. The *Persulphate* appears to have a similar constitution to the above ; both consisting of 1 1-2 proportion of acid, and 1 proportion of base.—They are, therefore, *sesqui-salts*. Indeed, as Dr. Thomson remarks, the tendency which peroxide of uranium has to form sesqui-salts, is very remarkable.—*First Prin.* ii. 40.

Among the native compounds of uranium, may be mentioned the *Green* and the *Yellow Uran-mica ;* and the *Protosulphate* and *Sub-persulphate*, discovered by Dr. John.

SECTION XXVIII.

COLUMBIUM.

Atom. Num. 185 ?—*Symb.* Cb.

This metal was discovered in 1801, by Mr. Hatchett, who detected it in a black mineral, supposed to have come from the United States, and, from this circumstance, applied to it the name of *Columbium.* About two years after, M. Ekeberg, a Swedish chemist, extracted the same substance from *Tantalite* and *Yttro-tantalite ;* and, on the supposition of its being different from columbium, described it under the name of *Tantalum.* The indentity of these metals, however, was established in the year 1809, by Dr. Wollaston.—*Phil. Trans.*

PROPERTIES. This metal, as prepared by Berzelius by heating potassium with the double fluoride of potassium and columbium, is a black powder, which does not conduct electricity, but in a denser state is a perfect conductor ; it does not melt at the temperature at which glass is fused ; by pressure it acquires a metallic lustre, and has an iron-gray colour ; it is scarcely acted on by the sulphuric, muriatic or nitro-muriatic acid, but is dissolved with heat and disengagement of hydrogen gas by hydrofluoric acid, and still more easily by a mixture of nitric and hydrofluoric acids; when heated in open air, it takes fire, and is converted into columbic acid.—*Berzelius*, ii. 515, *under the name of Tantalum.*

COLUMBIUM AND OXYGEN.

These bodies combine in two proportions, forming an oxide and an acid.

Oxide of Columbium.—Atom. Num. 201 ?—*Symb.* 2O+Cb.

This oxide is generated by placing columbic acid in a crucible lined with charcoal, luting carefully to exclude atmospheric air, and exposing it for an hour and a half to intense heat. The acid, where in direct contact with charcoal, is entirely reduced ; but the film of metal is very thin. The interior portions are pure oxide, of a dark gray colour, very hard and coherent. When reduced to powder its colour is dark-brown. It is not attacked by any acid, even by nitro-hydrofluoric acid ; but it is converted into columbic acid, either by fusion with hydrate of potassa, or deflagration with nitre. According to Berzelius this oxide occurs in combination with protoxide of iron and a little protoxide of manganese, at Kimito, in Finland.— *Traité de Chim.* ii. 527.

Columbic Acid.—Atom. Num. 209 ?—*Symb.* 3O+Cb.

PROPERTIES. This acid, as obtained in the form of hydrate by fusing yttro-tantalite with three or four times its weight of carbonate of potassa, and precipitating by acids, is tasteless and insoluble in water, but when placed on litmus paper communicates a red tinge ; it is soluble in many of the acids, but does not diminish their acidity; it unites readily with alkalies; and though it does not neutralize their properties completely, crystallized salts may be obtained by evaporation, called *Columbates ;* on applying heat to the hydrated acid, water is expelled, and the anhydrous columbic acid remains.

REFERENCES. *Thomson's First Prin.* ii. 74. *Berzelius, as above. The former chemists adopts a different view of the atomic constitution of these compounds from that entertained by the latter.*

Chloride of Columbium.—Columbium burns vividly in chlorine gas, and yields a yellow vapour, which condenses into a yellowish-white powder. This, by contact with water, is converted with a hissing noise, into columbic and muriatic acids.

Fluocolumbic Acid, is prepared by pouring hydrofluoric acid upon the columbic. It forms with bases, salts called *Fluocolumbates.*

Sulphuret of Columbium.—Rose first prepared this substance by heating columbium, at a low redness, in the vapour of sulphur, or by transmitting the vapour of bisulphuret of carbon over columbic acid, in a porcelain tube heated to whiteness.

SECTION XXIX.

CERIUM.

Atom. Num. 46.—*Symb.* Ce.

This metal was discovered in 1803, by Berzelius and Hisinger, in a rare Swedish mineral, called *Cerite.* It has since been found by Dr. Thomson, in a mineral from Greenland, called *Allanite.* It is but little known.

PROPERTIES. A solid, very brittle metal, of a whitish colour, and almost infusible; when heated to redness in the open air it is converted into a white oxide, and when heated intensely it is volatile; it is acted upon by nitro-muriatic acid.

Cerium may be obtained by subjecting its oxide to a high heat in combination with charcoal.

CERIUM AND OXYGEN.

There are two oxides of cerium, which have been studied by Hisinger, Vauquelin and Thomson.

Protoxide of Cerium.— *Atom. Num.* 54—*Symb.* O+Ce.

PROPERTIES. A white powder, which is insoluble in water, and forms salts with acids; it undergoes no change by exposure to air at common temperatures, but when heated in open vessels it absorbs oxygen, and is converted into the peroxide.

PREPARATION. This oxide is obtained by reducing cerite to powder, and dissolving it in nitro-muriatic acid. The solution is filtered, neutrallized with pure potassa, and then precipitated by tartrate of potassa; or, as Laugier recommends, by oxalic acid. This precipitate, well washed and afterwards calcined, is the protoxide of cerium.

Peroxide of Cerium.— *Atom. Num.* 58—*Symb.* 1½O+Ce.

This oxide is of a fawn-red colour; it is dissolved by several of the acids, but is a weaker base than the protoxide. It is obtained by decomposing the nitrate of the protoxide, or by heating the carbonate to redness in the open air.

REFERENCES. *Hisinger on the Oxides of Cerium, Ann. of Phil.* iv. 355. *Thomson's First Prin.* i. 379.

CERIUM AND SULPHUR.

Cerium may be combined with sulphur in two different ways. 1. By passing the vapour of carburet of sulphur over carburet of cerium, a light porous compound is obtained, of the colour of minium, which is not altered either by air or water. 2. By fusing oxide of cerium with a great excess of sulphuret of potassium, (*hepar sulphuris*,) the latter of which is removed by washing.—*Mosander, in Phil. Mag. and Ann.* i. 71.

Berzelius describes compounds of phosphorus, carbon and selenium, with cerium.— *Traité de Chim.* iii. 315.

SALTS OF CERIUM.

Permuriate of Cerium, crystallizes confusedly; is deliquescent, soluble in an equal weight of water, and in three or four parts of alcohol.

Nitric acid unites most easily with the white oxide. The solution

is very sweet, and is not crystallizable. When decomposed by heat it leaves a brick-coloured oxide.

Protosulphate of Cerium, occurs in white crystals, of a saccharine taste. It is formed by the action of sulphuric acid upon the white oxide. There is also a *Persulphate*.

Carbonate of Cerium, is a white powder, which assumes on drying a silvery appearance.

SECTION XXX.

TITANIUM.

Atom. Num. 24·3—*Symb.* Ti.—*Sp. gr.* 5·3.

This was first recognized as a new metal by Mr. Gregor, of Cornwall, in 1791, and its existence was afterwards established by Klaproth. Its properties, however, were first satisfactorily ascertained by Dr. Wollaston, in 1822, who found the native metal in a crystalline form.

PROPERTIES. Native titanium occurs in cubic crystals, whose colour and lustre are like burnished . copper ; it is so hard as to scratch rock crystal ; is exceedingly infusible, but when exposed to the united action of heat and air, the surface becomes covered with a purple film, which is an oxide ; it is oxidized by being strongly heated with nitre.

PREPARATION. Liebig obtains metallic titanium by putting fragments of recently made chloride of titanium and ammonia in a glass tube half an inch wide and two or three feet long, transmitting through it a current of perfectly dry ammonia, and when atmospheric air is entirely displaced, applying heat until the glass softens. Complete decomposition ensues, nitrogen gas is disengaged, muriate of ammonia sublimes, and metallic titanium is left in the state of a deep blue coloured powder. If exposed to the air while warm, it is apt to take fire.

REFERENCES. *Klaproth's Contribution*, i. *Wollaston, in Phil. Trans. for* 1823.

TITANIUM AND OXGYEN.

Titanium most probably combines in two proportions with oxygen.

Protoxide of Titanium is of a purple colour, and is supposed to exist pure in the mineral called *Anatase ;* but its composition and chemical properties are unknown.

Titanic Acid.—*Atom. Num.* 40·3—*Symb.* 2O+Ti.

PROPERTIES. When pure this substance is quite white ; it is exceedingly infusible, and difficult of reduction ; possesses weak acid properties, and according to Rose does not act as a base ; after exposure to a red heat it is not attacked by any acid except the hydrofluoric.

NATIVE STATE AND PREPARATION. Titanic acid, or the peroxide of titanium, exists in nearly a pure state in the *Titanite* or *Rutile*. From this mineral titanic acid is prepared by fusion with carbonate of potassa, dissolving the mass in concentrated muriatic acid, throwing down the oxide by dilution with water, and boiling; and finally, separating the impurities by digesting the precipitate while moist, with hydrosulphuret of ammonia.

REFERENCES. *Rose in Ann. de Chim. et de Phys.* xxiii. *For other processes, see Berzelius,* ii. 538 ; *and Rose's Manual of Analytical Chemistry.*

TITANIUM AND CHLORINE.

Bichloride of Titanium, was formed by Mr. George by passing dry chlorine over the pulverized native metal. A fluid condensed in the cool part of the tube, which was transparent, colourless, emitted dense white fumes, and boiled violently at a temperature little exceeding $212°$ F. On adding a drop of water to a few drops of this liquid, an almost explosive disengagement of chlorine ensued ; and when the water was not in excess, a solid salt was formed, the solution of which had all the properties of *Muriate of Titanium.* Rose prepared this compound by heating a mixture of the peroxide and charcoal in a tube, through which dry chlorine gas was passing : the resulting bichloride was purified from adhering to free chlorine by agitation either with mercury or potassium and repeated distillation.—*Ann. of Phil.* xxv. 18.

Fluotitanic Acid, formed by the action of fluoric upon titanic acid. It combines with bases and forms *Fluotitanates.*

TITANIUM AND SULPHUR.

Bisulphuret of Titanium, was formed by Rose, by passing sulphuret of carbon over titanic acid, strongly heated in a porcelain tube. It is of a deep green colour, and when rubbed with a hard substance, assumes a very strong metallic lustre like that of brass. It becomes very hot when nitric acid is poured upon it ; nitrous gas is disengaged and titanic acid is deposited in the state of a fine powder.

SECTION XXXI.

TELLURIUM.

Atom. Num. 64—*Symb.* Te.—*Sp. gr.* 6·245. *Berzelius.*

A very rare metal, hitherto found only in the gold mines of Transylvania, and even there in very small quantity. Its existence was inferred by Muller, in 1782, and fully established by Klaproth, in 1798.

PROPERTIES. Tellurium has a tin-white colour, running into lead-gray, a strong metallic lustre, and laminated texture ; it is very brittle ; when heated to full redness in a close vessel it volatilizes in the

form of a yellow gas, which condenses again in drops, and on cooling crystallizes in regular forms ; is fusible at a temperature below ignition; when heated before the blow-pipe it takes fire and burns rapidly, and is dissipated in gray coloured pungent inodorous fumes.

REFERENCES. *For a description of the mine of Nagyag in Transylvania, in which the Tellurium is found, see Travels by Dr. E. D. Clarke,* viii. 301, *Lond. Ed. A paper on the preparation of pure tellurium by Berzelius, Lond. and Edin. Phil. Mag.* vii. 539.

TELLURIUM AND OXYGEN.

Berzelius has obtained two compounds of tellurium and oxygen, both of which possess acid properties.

Tellurous Acid.— Atom. Num. 80—*Symb.* 2O+Te.

When tellurium is exposed to the action of the blow-pipe upon charcoal, it takes fire, and burns with a lively blue flame, the edges of which are green ; and it is completely volatilized in the form of a white smoke. This smoke is the tellurous acid, which may also be obtained by dissolving the metal in nitro-muriatic acid, and diluting the solution with a great quantity of water. It is fusible at a strong heat, and volatile at a still higher temperature. It forms a class of salts called *Tellurites ;* and can scarcely be made to act as a base.

Telluric Acid.— Atom. Num. 88—*Symb.* 3O+Te.

This acid is obtained, according to Berzelius by submitting the tellurous acid in solution with excess of caustic alkali to a current of chlorine, till the precipitate which at first falls, is entirely redissolved. Chloride of barium is added to precipitate any sulphuric or selenic acid which may be present, after which the solution is saturated with ammonia, and the tellurate of barytes precipitated by chloride of barium, collected and washed with cold water. This salt is decomposed by sulphuric acid, and the concentrated solution deposites the telluric acid in beautiful crystals.—[For details concerning this and the preceding acid, see a notice of the recent researches of Berzelius in *Johnston's Reports on Chemistry.*]

TELLURIUM AND CHLORINE.

Chlorides of Tellurium.—These have been recently examined by Rose. When the metal is *gently* heated in chlorine gas, a white crystalline compound is formed, consisting of two atoms chlorine+one atom tellurium. It has much resemblance to the solid chloride of selenium. When the metal is *strongly* heated in the same gas, violet vapours are formed, which condense into a black deliquescent mass. When freed as much as possible from bichloride, this substance was found to consist of one atom chlorine+one atom tellurium.

TELLURIUM AND HYDROGEN.

Telluretted Hydrogen.—A gaseous substance discovered by Sir H. Davy, in 1809. It is colourless, has an odour similar to that of sulphuretted hydrogen, and is absorbed by water, forming a claret coloured solution. As it unites with alkalies it may be regarded as a feeble acid. It reddens litmus paper at first, but loses this property after being washed with water.

Berzelius also describes compounds of sulphur, selenium, aluminum and glucinum with tellurium.— *Traité de Chim.* ii. 520. *Johnston's Report.*

CLASS V.

ORDER II.

METALS WHICH DO NOT FORM ACIDS.

SECTION XXXII.

BISMUTH.

Atom. Num. 71.—*Symb.* Bi.—*Sp. gr.* 9·822.

This metal was known as early as 1520; but the first satisfactory account of it was published by Geoffry, in 1723.

PROPERTIES. Bismuth has a reddish white colour and considerable lustre; its structure is highly lamellated, and when slowly cooled it crystallizes in octahedrons; it is brittle when cold, but may be hammered into plates while warm,; fuses at 476° F.* and sublimes in close vessels at about 30° of Wedgewood; is but little changed by exposure to air at common temperatures, but when fused in open vessels it becomes oxidated, and when heated to the subliming point, it burns with a bluish-white flame, and emits copious fumes of the oxide of bismuth.

NATIVE STATE AND EXTRACTION. Bismuth is rarely found native, but it is often met with in combination with oxygen, sulphur and arsenic. It may be obtained pure for chemical purposes, by heating the oxide or subnitrate to redness along with charcoal.

BISMUTH AND OXYGEN.

These two bodies combine only in one proportion, though Berzelius considers the film formed on the surface of the metal, when exposed to the air, as a *Suboxide.—Traité de Chim.* iii. 151.

Oxide of Bismuth.—Atom. Num. 79—*Symb.* O+Bi.

A yellow coloured powder, sometimes called *Flowers of Bismuth*, which, at a full red heat, is fused, and yields a transparent yellow glass, and, at a higher temperature, is sublimed; it unites with acids, and most of its salts are white.

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* Marx has ascertained that bismuth at the moment of solidifying expands 1·53rd of its volume. He considers also that, like water, it has in the fluid state a point of maximum density.—*Johnston's Report on Chemistry.*

Crystallization of Bismuth.—Dumas states that this experiment does not succeed with the bismuth of commerce, because the metal is alloyed with arsenic or antimony which greatly modify the crystallization. It is necessary to free it of these bodies which can be done by heating it to redness with a little nitrate of potash and repeating the operation until the crystallization becomes fine and easy. The crystals afforded by pure bismuth are large and have the most vivid colours of the spectrum, probably in consequence of the production of a thin film of oxide on their surface. The manipulation is similar to that employed in the crystallization of sulphur. See page 150.

This oxide is formed by exposing the metal to heat, and air, or by heating the subnitrate to redness.

REFERENCES. *Lajerhielm's Experiments to determine the proportion in which Bismuth unites with Sulphur and Oxygen, Ann. of Phil.* iv. 357. *Dr. Davy, in Phil. Trans. for* 1812. *Thomson's First Prin.* i. 407.

BISMUTH AND CHLORINE.

Chloride of Bismuth.—*Atom. Num.* 106·45—*Symb.* Cl+Bi.

A substance of a grayish-white colour, granular texture, which is opaque, and is not sublimed by heat ; formerly called *Butter of Bismuth.* It may be prepared by introducing bismuth, in fine powder, into chlorine gas ; or by heating two parts of corrosive sublimate with one of bismuth, and afterwards expelling the excess of the former, together with metallic mercury, by heat.

BISMUTH AND BROMINE.

Bromide of Bismuth.—A solid, of a steel-gray colour, having the aspect of iodine, fused into a solid mass. It fuses at 392° F. and then assumes a hyacinth red colour, but resumes its former colour on cooling. It may be formed by exposing to heat bismuth in powder with a great excess of bromine in a long tube shut at one end. The bromide of bismuth is found at the bottom of the tube.—*Serullas.*

BISMUTH AND IODINE.

Iodide of Bismuth, may be formed by heating that metal with iodine. It is of an orange colour, and insoluble in water. With hydriodic acid or hydriodate of potassa, nitrate of bismuth affords a deep chocolate coloured precipitate.

BISMUTH AND SULPHUR.

Sulphuret of Bismuth.—*Atom. Num.* 87—*Symb.* S+Bi.

Bismuth combines readily with sulphur and forms a bluish-gray sulphuret, having a metallic lustre. The same compound is also found native in Cornwall, Bohemia, Saxony and Sweden.

BISMUTH AND THE METALS.

Bismuth is capable of being alloyed with most of the metals, and forms, with some of them, compounds of remarkable fusibility. One of these is Sir Isaac Newton's *Fusible Metal.* It consists of eight parts of bismuth, five of lead, three of tin, or, according to Dobereiner, when made in the best proportions, it is a compound of 1 atom of lead, 1 of tin and 2 atoms of bismuth, or an atom of the binary alloy of bismuth and lead, united with an atom of the binary alloy of bismuth and tin. [*Ann. of Phil.* xxv. 389.] When thrown into water it melts before the water is heated to the boiling point. It is from the property of forming fusible alloys, that bismuth enters into the composition of several of the *soft solders,* which indeed, is its principal use in the arts.

Bismuth, like antimony, has the singular property of depriving gold of its ductility—even when combined with it in very minute proportion. This effect is produced by merely keeping gold in fusion near melted bismuth. It has, nevertheless, been employed, by Chaudet in cupellation.—*Ann. de Chim. et de] Phys.* viii. 113. *Henry,* ii.-107.

SALTS OF BISMUTH.

Nitrate of Bismuth.—*Atom. Num.* 160—*Symb.* (5O+N)+(O+Bi.) +3 aq.

A transparent crystalline salt, which is decomposed by water, a white subnitrate being precipitated, which is called *Magistery of Bismuth,* or *Pearl White,* in which state it is employed in medicine. The solution is also employed for forming a white sympathetic ink.

It is prepared by dissolving bismuth in dilute nitric acid, in the proportion of one part of the former to one and a half parts of the latter. The bismuth is to be broken into small pieces and added at distant intervals.

The subnitrate of bismuth, in large doses, is an active poison.— *See Christison,* 371.

Sulphate of Bismuth.—*Atom. Num.* 119—*Symb.* (3O+S)+(O+Bi.)

This salt occurs in the form of a white powder, or in needles; it is insoluble in water, but is decomposed by it, and converted into a *Subsulphate* and *Supersulphate.* [*Webster's Brande.*] It is formed by the action of hot and concentrated sulphuric acid upon metallic bismuth.

Carbonate of Bismuth.—*Atom. Num.* 277—*Symb.* (2O+C)+(3O+Bi.) +2 aq.

A white tasteless powder, quite insoluble in water ; formed by decomposing nitrate of bismuth by an alkaline carbonate.

REFERENCES. *For description of several other salts of Bismuth, see Thomson's First Prin.* ii. 389, *and Inorg. Chem.*

TESTS OF THE SALTS OF BISMUTH.

Water poured into a colourless solution of these salts, produces a white precipitate. Gallic acid occasions an orange yellow, and ferrocyanate of potassa a yellowish precipitate.

SECTION XXXIII.

COPPER.

Atom. Num. 31·6—*Symb.* Cu.*—*Sp. gr.* 8·895.

This metal was known in the earliest ages of the world.

PROPERTIES. Copper is distinguished from all other metals, titanium excepted, by having a red colour; it receives a considerable lustre by polishing; it is both ductile and malleable, and, in tenacity, is inferior only to iron; it is hard and elastic, and consequently sonorous; in fusibility it stands between silver and gold; it undergoes little change in a perfectly dry atmosphere, but is rusted in a short time by exposure to air and moisture, being converted into a green substance, the carbonate of the black oxide of copper; at a red heat it absorbs oxygen, and is converted into the oxide, which appears in the form of black scales.

NATIVE STATE AND EXTRACTION. Native copper is by no means uncommon. It occurs in large amorphous masses in the northwestern parts of this continent, and is sometimes found in octahedral crystals, or in forms allied to the octahedron. It also occurs in various states of combination, as the oxide, chloride, sulphuret, &c. Perfectly pure copper may be obtained by dissolving the copper of commerce in muriatic acid; the solution is diluted and a plate of iron immersed, upon which the copper is precipitated. It may be fused into a button, after having been previously washed in dilute sulphuric acid to separate a little iron that adheres to it.

*. REFERENCES. *For localities of Native Copper, see Cleaveland's Mineralogy. Vauquelin on precipitating Copper by Iron and Zinc, Ann. de Chim.* lxxxvii. 16, *or Ann. of Phil.* iv. 157. *Dr. Cooper on the reduction, &c. of the Ores of Copper, Emporium of Arts.* ii. 215. *An article on Mining in Copper and Tin in Cornwall, in the Quarterly Review,* xxxvi. 81.

COPPER AND OXYGEN.

Three distinct oxides of copper are now recognized by chemists.

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* From the latin *Cuprum.*

Red or Suboxide of Copper.—Atom. Num. 71·2—*Symb.* O+2 Cu.

PROPERTIES. Orange yellow, in the state of hydrate, red when pure; fusible, below a red heat, into a reddish mass; absorbs oxygen gas at a temperature slightly elevated and passes into the state of oxide; it forms a colourless solution with ammonia, which becomes blue by exposure to the air.

NATIVE STATE AND PREPARATION. This oxide occurs native in the form of octahedral crystals, and is found, of peculiar beauty, in the mines of Cornwall. It may be prepared artificially by heating in a covered crucible a mixture of 31·6 parts of copper filings with 39·6 of the black oxide; or still better by arranging thin copper plates one above the other with interposed strata of the black oxide, and exposing them to a red heat carefully protected from the air. It may also be obtained by boiling a solution of the acetate of copper with sugar, when the suboxide subsides as a red powder.

Black or Protoxide of Copper.—Atom. Num. 39·6—*Symb.* O+Cu.

PROPERTIES. Colour varying from a dark brown to a bluish black, according to the mode of formation; undergoes no change by heat alone, but is readily reduced to the metallic state by heat and combustible matter; is soluble in ammonia, forming with it a deep blue solution, by which it is distinguished from all other substances.

NATIVE STATE AND PREPARATION. This oxide of copper, the *Copper Black* of mineralogists, is sometimes found native, being formed by the spontaneous oxidation of other ores of copper. It may be prepared artificially, by calcining metallic copper, by precipitation from the salts of copper by means of pure potassa, and by heating the nitrate of copper to redness.

Peroxide of Copper.—Atom. Num. 47·6—*Symb.* 2O+Cu.

This oxide was prepared by Thenard by the action of peroxide of hydrogen diluted with water on the hydrated black oxide. It suffers spontaneous decomposition under water; but it may be dried *in vacuo* by means of sulphuric acid. When thrown upon a red hot coal it detonates, and the copper is reduced. It is insoluble in water and does not alter the colour of litmus paper. Acids decompose it into oxide of copper and peroxide of hydrogen.

REFERENCES. *Proust's Experiments on Copper and its compounds, Ann. de Chim.* xxv. *or Repert. of Arts,* 1st ser. xiv. 114, 201, *Chenevix, in Phil. Trans. for* 1806. *Thenard, Traité de Chim.* ii. 379, *where three Oxides are described; and Berzelius,* iii. 128.

COPPER AND CHLORINE.

From the researches of Proust and Dr. J. Davy, there appears to be no doubt that there are two compounds of these substances, and that they are proportional to the oxides of copper.

Subchloride of Copper.—*Atom. Num.* 98·65—*Symb.* Cl+2 Cu.

SYN. *Rosin of Copper*—Boyle. *White Muriate of Copper*—*Proust.*

PROPERTIES. Colour varying with the mode of preparation, being white, yellow, or dark brown; it is insoluble in water, but soluble in muriatic acid, and is precipitated unchanged by water; is fusible at a heat just below redness, and bears a red heat in close vessels without subliming.

PREPARATION. This compound may be conveniently prepared by heating copper filings with twice their weight of corrosive sublimate; or by the action of protomuriate of tin on the muriate of copper; and also by decomposing the muriate by heat.

Chloride of Copper.—*Atom. Num.* 67·05—*Symb.* Cl+Cu.

A pulverulent substance of a yellow colour, which deliquesces on exposure to the air, and is reconverted by water into the *muriate.* It is formed by exposing the muriate of copper to a temperature not exceeding 400° F.—*Dr. J. Davy, in Phil. Trans. for* 1812.

Iodide of Copper, is formed by dropping aqueous hydriodate of potassa into a solution of any cupreous salt. It is an insoluble dark brown powder.

COPPER AND SULPHUR.

Disulphuret of Copper.—*Atom. Num.* 79·2—*Symb.* S+2 Cu.

A natural production well known to mineralogists under the name of *Copper Glance;* and in combination with sulphuret of iron, it is a constituent of the variegated copper ore. It is formed artificially, by heating copper filings with a third of their weight of sulphur. The combination is attended with such free disengagement of caloric, that the mass becomes vividly luminous.

Sulphuret of Copper.—*Atom. Num.* 47·6—*Symb.* S+Cu.

A constituent of *Copper Pyrites,* in which it is combined with protosulphuret of iron. It may be formed artificially by the action of sulphuretted hydrogen on a per-salt of copper. When exposed to a red heat in a close vessel, it loses half its sulphur, and is converted into a protosulphuret.

It is from this compound that most of the copper of commerce is obtained. The small quantity of arsenic, and the sulphur which it contains, are separated by roasting; and the copper is obtained by repeated fusions, in some of which an addition of charcoal is made. See *R. Phillips on Yellow Copper Ore, Ann. of Phil.* xix. 296.

COPPER AND PHOSPHORUS.

Copper unites by fusion with phosphorus. The phosphuret is white, brittle, and of the specific gravity 7·122. It consists of one atom phosphorus+2 atoms copper. There are probably several distinct phosphurets of copper.

COPPER AND THE METALS.

Many of the alloys of copper are of the highest importance in domestic economy and the arts.

Copper may be united to iron by fusion, but not without some difficulty. It is an alloy of a gray colour, has but little ductility and is much less fusible than copper. According to Thenard it is attracted by the magnet even when the iron constitutes only 1-10 of the alloy. [*Ann. de Chim.* 1. 131.] And from some observations of M. Levavasseur it appears probable that the variety of iron, called *hot short* iron, because it is brittle when red hot, owes its peculiarity to the presence of copper.—See *Thomson's Inorg. Chem.* i. 598. *Also D. Mushet on the practicability of alloying iron and copper, Lond. and Edin. Phil. Mag.* vi. 81.

Bronze, is an alloy of 11 parts of tin to 100 of copper. It is of a grayish-yellow colour, harder and more fusible than copper, slightly malleable when slowly cooled, and very much so when heated to near redness and then plunged into cold water. In consequence of the fusibility of this alloy, it is much used in the casting of statutes. According to Puymaurin, the finest French bronze medals consist of from 7 to 11 of tin and 100 of copper.— *Thenard.*

Bell Metal, is an alloy of 22 parts of tin and 78 of copper. It is solid, fine and close grained, of a grayish-white colour, and more fusible than bronze. The Chinese *Tam-Tam* or *Gong,* so celebrated for the richness of its tones, contains, according to the analysis of Thenard, 80 parts of copper and 20 of tin. *Speculum Metal,* from which the mirrors of telescopes are made, contains about two parts of copper and one of tin. The whiteness of the alloy is improved by the addition of a little arsenic.

Brass, consists of copper, alloyed with from 12 to 25 per cent. of zinc ; the proportions differing somewhat in almost every place in which it is manufactured. It has a yellow colour, is very malleable and ductile when cold, but fragile at an elevated temperature. The preparation consists in uniting directly the proper proportions of zinc and copper, in the ordinary way, or in heating a mixture of carbon, copper and calamine, (carbonate of zinc,) which is an abundant natural product.

The compounds known under the names of *Tombac, Dutch Gold, Prince Rupert's Metal,* or *Pinchbeck,* are alloys, containing more copper than exists in brass, and they are consequently made by fusing various proportions of copper with brass.

The art of *tinning copper* consists in applying to this metal a very thin covering of tin, in order to protect its surface from oxidation. The copper is first sprinkled over with some muriate of ammonia ; it is then heated and rubbed with this salt. When the copper is perfectly clean, small fragments of tin are placed upon it, and it is then heated sufficiently for melting the tin ; this, when liquified, is rubbed over the whole sheet of copper, and if the process is dexteriously performed, adheres uniformly to its surface.[*]

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[*] According to Mr. Donovan the coat of tinning which is given to the inside

- REFERENCES. *Bishop Watson's Chemical Essays*, iv. *Aikin's Chem.
Dict. article, Brass, &c. Thenard, Traité de Chim.* i. 628. *The art.
Brass, by Mr. C. Sylvester, and the art. on Bronzing, by J. G. Dalyell,
in the Supp. to the Edin. Encyclopedia. Dalton's New Syst.* ii.

SALTS OF COPPER.

Muriates of Copper.—Corresponding with the two chlorides of copper we have also a *Submuriate* and a *Muriate*. The former is obtained by digesting metallic copper in muriatic acid, with the oxide—The latter by dissolving oxide of copper in muriatic acid.

Nitrate of Copper.—Atom. Num. 156·6—*Symb.* $(5O+N)+(O+Cu)$
$+7$ aq.

PROPERTIES. This salt crystallizes, though with some difficulty, in prisms, which are of a deep blue colour, and deliquesce on exposure to the air; by exposing them to heat, a green insoluble *Sub-nitrate* is formed, which contains, exclusive of water, one atom of acid and two atoms of the oxide.

When crystals of nitrate of copper are coarsely powdered, sprinkled with a little water and quickly rolled up in a sheet of tin foil, there is great heat produced, nitrous gas is rapidly evolved, and the metal often takes fire. These crystals also detonate when mixed with phosphorus and struck with a hammer.

This salt is prepared by the action of nitric acid on copper.

Ammoniuret of Copper.—Copper and its oxides are soluble in ammonia. The watery solution of ammonia, at its boiling temperature, acts rapidly on copper. Dry ammonical gas appears also to combine with heated copper. [*Brande's Journal*, 29, 158.] If ammonia be added in excess to nitrate of copper, the precipitate which is first formed is re-dissolved. On this property depends the method of separating oxide of copper from other metallic oxides; from those of iron, for instance, which are not soluble by ammonia.—*Henry*, ii. 112.

Oxide of copper digested in ammonia, forms a bright blue liquid; from which by careful evaporation, fine blue crystals may be obtained, called *Ammoniuret of Copper.* Suboxide of copper also dissolves in ammonia, and yields a colourless solution, which becomes blue by exposure to the air, in consequence of the absorption of oxygen.

Plates of copper digested in a solution of muriate of ammonia, are soon incrusted with a green powder, which has been used in the arts under the name of *Brunswick Green.*

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of copper vessels is in fact a mixture of lead and tin; and the use of it is to prevent the copper from coming in contact with the food prepared in such a vessel, which might otherwise be impregnated with that poisonous metal.— Although lead itself is a poisonous metal, it is singular that the presence of tin renders it innoxious; the reason of which is that tin prevents the lead from dissolving. Pewter is composed of lead in tin; and on account of the presence of the latter, the former is rendered safe.— *Donovan's Chemistry*, 249.

Sulphate of Copper.—Atom. Num. 124·6—*Symb.* (3O+S)+(O+Cu.)
+5 aq.

SYN. *Blue Vitriol—Roman Vitriol.*

This salt is crystalline, of a fine blue colour, and soluble in four parts of water at 60° F. ; it slightly effloresces on exposure to the air, and undergoes by a gentle heat the aqueous fusion. The solution of this salt is decomposed by pure and carbonated alkalies. The former, however, re-dissolve the precipitate. Thus on adding pure liquid ammonia to a solution of sulphate of copper, a precipitate appears, which on a farther addition of the alkali is re-dissolved, and affords a beautiful bright blue solution.

PREPARATION. This salt may be prepared for chemical purposes by dissolving black oxide of copper in dilute sulphuric acid ; but it is procured for sale by roasting the native sulphuret. It is used in medicine as an escharotic ; in the arts, for obtaining Scheele's green, &c.

This salt as well as most of the soluble salts of copper, is poisonous when taken internally. The remedy proposed by Orfila in such cases is albumen, with which oxide of copper forms an inert compound. See *Christison on Poisons*, 353.

There appears to be no sulphate of the suboxide of copper.

Disulphate of Copper, is formed by adding solution of potassa to the above sulphate. It is a pale bluish green powder, and is composed of one atom of acid+two atoms of the oxide.

Phosphate of Copper.—This has not yet been formed artificially, but has been found native in a white quartz rock. It is of an emerald-green colour, and is not crystallized.—*Henry*, ii. 115. *Lunn's Analysis of native Phosphate of Copper, Ann. of Phil.* xix. 179.

Biphosphate of Copper.— A bluish-green salt, formed by mingling together phosphate of soda and sulphate of copper.

Carbonate of Copper.—According to Mr. Phillips, three native carbonates of copper are at present known,—the green, the blue, and the anhydrous. The green is the beautiful mineral known by the name of *Malachite*, and consists of one atom of carbonic acid, two atoms oxide of copper, and one of water. A similar compound may be made from the persulphate by double decomposition, or by exposing metallic copper to air and moisture.

The blue pigment called *Verditer*, said to be prepared by decomposing nitrate of copper by chalk, is an impure carbonate.—*On the Carbonates of Copper and the preparation of Verditer, see the valuable Essay of Mr. Phillips, in Brande's Jour.* iv. 273.

Ferrocyanate of Copper—is a brown compound, obtained by adding ferrocyanate of potassa to a dilute solution of sulphate or nitrate of copper. Mr. Hatchett has recommended this substance as a brown pigment.—*Repert. of Arts.* 2d *ser.* ii. 180.

Chromate of Copper.—This salt is prepared by precipitating sulphate of copper by chromate of potash. It is of a reddish brown colour, is soluble in dilute solution of ammonia, producing a clear solution of a beautiful and deep green colour. When the solution is evaporated, the reddish chromate of copper appears as the ammonia flies off. The

readiest way of preparing this permanent and beautiful colour, is to add solution of chromate of potash to ammoniacal sulphate of copper.

The *Acetates of Copper* will be noticed under Acetic acid.

TESTS OF THE SALTS OF COPPER. The cupreous salts are nearly all soluble in water, and of a blue or green colour. Ammonia produces a compound of a very deep blue, when added in excess to these solutions; hydrosulphuret of ammonia forms a black precipitate; and a plate of iron plunged into a liquid salt of copper, precipitates metallic copper. Ferrocyanate of potassa is also an excellent test of the presence of copper; it produces a brown cloud in solutions containing the oxide. All the salts of copper communicate a green tint to inflammable matter in a state of combustion when moistened.

SECTION XXXIV.

LEAD.

Atom. Num. 103·5—*Symb.* Pb.*—*Sp. gr.* 11·352.

Known from the most remote antiquity, and called *Saturn* by the Alchemists.

PROPERTIES. This metal is of a bluish-white colour, and when recently cut or melted, exhibits considerable lustre, which soon, however, tarnishes; its malleability is sufficient to allow of its being beaten into very thin leaves; and it may be drawn into wire, which has less tenacity, however, than that of most other metals; it melts, according to Morveau, at 590° F. but according to Mr. Crichton, of Glasgow, at 612°; exposed to a red heat, with free access of air, it smokes and sublimes, and gives off a gray oxide, which collects on surrounding bodies; it is slowly oxidized also, by exposure to the atmosphere at common temperatures, and more rapidly when exposed alternately to the action of air and water. Many spring-waters, however, owing to the salts which they contain, do not corrode lead.—*On this subject, see Christison on Poisons,* 391.

NATIVE STATE AND PREPARATION.—Native lead is an exceedingly rare production, but in combination, especially with sulphur, it occurs in large quantity. From the native sulphuret, the *Galena* of mineralogists, all the metallic lead of commerce is extracted.

This lead generally contains copper and iron, and sometimes traces of silver. To obtain it in a state of perfect purity, it should be dissolved in nitric acid, and the solution evaporated and crystallized several times. The resulting nitrate reduced to powder, is to be strongly heated in a Hussian crucible to drive off the nitric acid, and then melted in contact with a small quantity of charcoal.—*Berzelius, Traité de Chim.* iii. 176.

* From the latin word *Plumbum.*

LEAD AND OXYGEN.

There appear to be three oxides of lead. These have been examined with great care by Berzelius.

Protoxide of Lead.—Atom. Num.—111·5—Symb. O+Pb.

PROPERTIES. Yellow, tasteless, insoluble in water, but soluble in potassa and in acids; when heated it forms, on cooling, a yellow semitransparent glass, called *Litharge*, which is, to a considerable degree, volatile at a red heat, and has been obtained in regular crystals. [*Phil. Mag. and Ann.* i. 312.] Another form of the yellow oxide is, that which is known in commerce by the name of *Massicot:*

PREPARATION. The yellow oxide may be obtained by decomposing nitrate of lead with carbonate of soda, and igniting the precipitate, or by heating the nitrate to redness in a close vessel. Massicot is prepared by collecting the gray film which forms on the surface of melted lead, and exposing it to heat and air, until it acquires a uniform yellow colour.

Sesquioxide of Lead.—Atom. Num. 115·5—*Symb.* 1½O+Pb.

This oxide, which, in an impure form, is the *Minium* or *Red Lead* of commerce, does not unite with acids; when heated to redness it gives off pure oxygen gas, and is reconverted into the protoxide; when digested in nitric acid, it is resolved into the protoxide and peroxide of lead, the former of which unites with the acid, while the latter remains as an insoluble powder.

This compound is formed by heating litharge in open vessels, while a current of air is made to play upon its surface. The common red lead generally contains a proportion of protoxide and sulphate of lead, and other impurities.

Peroxide of Lead.— Atom. Num. 119·5—*Symb.* 2O+Pb.

This oxide is of a puce colour, does not unite with acids, and by a red heat is resolved into the protoxide and oxygen gas.

It may be obtained by the action of nitric acid on minium; but the most convenient method of preparing it, is by transmitting a current of chlorine gas through a solution of the acetate of lead. In this process, water is decomposed; its hydrogen uniting with chlorine, and its oxygen with the protoxide of lead, give rise to muriatic acid, and the peroxide of lead.

Ignition of Peroxide of Lead.—When eight parts of peroxide of lead are mixed with two and a half parts of pure and dry tartaric acid in a dry capsule, ignition very soon occurs throughout the whole mass, which is very vivid and of long duration. Oxalic and citric acids operate in a similar manner upon peroxide of lead, but the action of the former is perhaps more rapid and stronger than tartaric acid, while the latter is rather weaker. Minium, litharge and carbonate of lead mixed with tartaric acid yield also, according to M. Boetliger, pyrophori, but not so good as those yielded by the pure oxide.—*Lond. and Edin. Phil. Mag.* x. 319.

REFERENCES. *Berzelius on the Oxides of Lead, Ann. of Phil. XV,* 94.—*Longchamp, Ann. de Chim. et de Phys.* xxxiv. 105, *who denies that Minium is a peculiar Oxide of Lead. Thomson's First Prin.* i. 396, On the Manufacture of Red Lead, see Aikin's Chem. Dict. and Watson's Chem. Essays.

LEAD AND CHLORINE.

Chloride of Lead.—Atom. Num. 138·95—*Symb.* Cl+Pb.

PROPERTIES. This compound has a sweet taste, and is soluble in 22 parts of water at 60° F., and also in dilute nitric acid; when dry it is fusible at a heat below redness, into a semi-transparent substance of the consistence of horn, from whence it has been called *Horn Lead,* or *Plumbum Corneum ;* by an intense heat it is volatilized.

It is slowly formed by the action of chlorine gas on thin plates of lead, and may be obtained more easily by adding muriatic acid or a solution of sea-salt, to the acetate or nitrate of lead dissolved in water.

Mineral or Patent Yellow.—The pigment known under this name is a compound of the chloride and protoxide of lead. It is prepared for the purposes of the arts by the action of moistened sea-salt on litharge, by which means a portion of the protoxide is converted into chloride of lead, and then fusing the mixture. Soda is set free during this process, and is converted into a carbonate by absorbing carbonic acid from the atmosphere.

LEAD AND IODINE.

Iodide of Lead.—Atom. Num. 229·5—*Symb.* I+Pb.

This compound is easily formed by mixing a solution of hydriodic acid or hydriodate of potassa with the acetate or nitrate of lead dissolved in water. It is of a rich yellow colour ; is dissolved by boiling water, forming a colourless solution, and is deposited, on cooling, in yellow crystalline scales of a brilliant lustre.

LEAD AND SULPHUR.

Sulphuret of Lead.—Atom. Num. 119·5—*Symb.* S+Pb.

This is an abundant natural product, known by the name of *Galena,* from which the lead of commerce is obtained by roasting the ore to drive off the sulphur. It occurs massive and crystallized, the primitive form being the cube. It often contains traces of silver in such quantity as to be worth the trouble of separation. It occurs very abundantly in the western parts of the United States. It may be made artificially either by heating together lead and sulphur, or by the action of sulphuretted hydrogen on a salt of lead.

There appear to be two other sulphurets of lead, which Dr. Thomson names *Disulphuret* and *Bisulphuret of Lead.—Inorg. Chem.* i. 566.

Lead may also be made to combine with phosphorus and carbon.

REFERENCES. *Descostils on the Sulphuret of Lead, copied from Memoirs D'Arcueil, in Repert. of Arts*, 2d ser. xvi. 280. *Berthier's Memoir on the decomposition of Sulphuret of Lead by Carbonate of Soda, Ann. de Chim. et de Phys.* xxxiii. 154. *On the reduction of Lead from the sulphuret, &c., see Aikin's Chem. Dict. and Dr. Cooper, in Emporium of Arts*, v. 177.

LEAD AND THE METALS.

The alloys of lead are quite numerous ; but those which it forms with tin are the most important. The compound of one part of tin and two of lead is known by the name of *Plumber's solder*, from the uses to which it is applied. If we employ 3 parts of lead, the compound is still more fusible. Common *Pewter* consists of 80 parts of tin and 20 of lead ; and what is termed *Pot metal*, consists of copper with about a fourth of its weight of lead.

Lead when added only in small quantities, impairs the ductility of silver and gold.

SALTS OF LEAD.

The salts of lead all contain the protoxide as the basis.

Nitrate of Lead.—*Atom. Num.* 165·5—*Symb.* $(5O+N)+(O+Pb.)$

This salt occurs in large white opake octahedral crystals, which are anhydrous, and have an acid reaction, though neutral in their composition. It is prepared by digesting litharge in dilute nitric acid.

A *subnitrate* or *dinitrate* of *lead*, composed of one proportion of acid to two proportions of the protoxide, was formed by Berzelius by adding to a solution of the neutral nitrate, a quantity of pure ammonia, insufficient for separating the whole of the acid.

Sulphate of Lead.—*Atom. Num.* 151·5—*Symb.* $(3O+S)+(O+Pb.)$

This salt occurs native in regular crystals, though from its insolubility it cannot be crystallized artificially. The primary form of the crystals is a right rhombic prism. It is anhydrous, though there is usually a trace of water mechanically lodged between the plates of the crystals. Its insolubility both in water and in nitric acid, renders its formation of use as a step in mineral analyses. Hence also it is not poisonous, and therefore any soluble sulphate renders the active salts of lead inert.

Sulphuric acid can only be made to act upon lead when concentrated, and at a boiling temperature, and hence lead is employed in constructing chambers for the manufacture of this acid. Sulphate of lead may, however, be artificially prepared by adding sulphuric acid, or still better, sulphate of soda, to any of the salts of lead.

REFERENCES. *Berthier on the uses to which Sulphate of Lead may be applied in the arts, Ann. de Chim. or Repert. of Arts*, 2d ser. xlii. 110, 184.

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✝ *Phosphate of Lead.*—*Atom. Num.* 147·2—*Symb.* $(2\frac{1}{2}O+P)+(O+Pb.)$

This salt is of a yellowish white colour, insoluble in water, soluble in alkaline solutions and in nitric acid ; is decomposed by sulphuric and hot muriatic acid ; fuses before the blow-pipe, and crystallizes on cooling.

Phosphate of lead exists native, and is often crystallized in six-sided prisms. It is formed artificially by mixing solutions of nitrate of lead and phosphate of soda, or phosphoric acid.

According to Thomson there is also a *Diphosphate of Lead*, consisting of one proportion of phosphoric acid and two proportions of protoxide of lead.—*First Prin.* ii. 370.

✝ *Carbonate of Lead.*—*Atom. Num.* 133·5—*Symb.* $(2O+C)+(O+Pb.)$

This salt, which is the *White Lead* or *Ceruse* of painters, occurs native, but may be obtained by double decomposition. It is prepared for the purposes of commerce by exposing coils of thin sheet lead to the vapour of vinegar, when by the action of the acid fumes, the lead is both oxidized and converted into a carbonate.

This substance in commerce is often adulterated with chalk, sulphate of lead and sulphate of barytes.

REFERENCES. *For the process of making White Lead, see Aikin's Chem. Dict. art. Lead. For notices of other Salts of Lead, see Thomson's First Prin.* ii. 367. *Chevreul on the Nitrates and Nitrites of Lead, Ann. of Phil.* i. 301. *Berzelius' Analyses of the Salts of, Ann. of Phil.* vii. 40. *On the poisonous properties of these Salts, consult Christison on Poisons.*

TESTS OF THE SALTS OF LEAD. The soluble salts of lead have a sweetish austere taste, and are characterized by the white precipitate produced by ferrocyanate of potassa, the deep brown by hydrosulphuret of ammonia, and the yellow by hydriodate of potassa.

The salts insoluble in water are dissolved by soda, potassa, and by nitric acid, when the metal is rendered manifest by sulphuretted hydrogen, and other tests. Heated by the blow-pipe upon charcoal, they afford a button of metal.

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* Dr. Turner, upon the authority of Dr. A. T. Thomson, states a curious fact with regard to the poisonous property of the salts of lead; which is, that of all the ordinary preparations of lead, the carbonate is by far the most virulent poison. Any salt of lead which is easily convertible into the carbonate, as for instance, the subacetate, is also poisonous ; but Dr. Thomson has given large doses of the nitrate and muriate of lead to rabbits without producing perceptible inconvenience. He finds that acetate of lead, mixed with vinegar to prevent the formation of any carbonate, may be freely and safely administered in medical practice.

Sulphate & magnesia or soda.

Lime water is good for painters to drink.

✝ *Antidote.*

CLASS VI.

METALS, THE OXIDES OF WHICH ARE DECOMPOSED BY A RED
HEAT.

SECTION XXXV.

MERCURY.

Atom. Num. 200.— *Symb.* Hg.*— *Sp. gr.* 13.568.

This metal was known to the ancients. It received the name of *Quicksilver* from the alchemists. It occurs native, or in combination with sulphur, forming *Cinnabar*, from which the metal may be separated by distillation with quicklime or iron filings.

PROPERTIES. Mercury is distinguished from all other metals by being fluid at the ordinary temperature; it has a tin-white colour, and strong metallic lustre; becomes solid at the temperature of 39° or 40° below zero, and in congealing, evinces a strong tendency to crystallize in octahedrons; it contracts greatly at the moment of congelation, for while its density at 47° F. is 13.545, the specific gravity of frozen mercury is 15.612; when solid it is malleable, and may be cut with a knife; at 662° F. according to Petit and Dulong, it enters into ebullition, and condenses again on cool surfaces into metallic globules; it is not changed by the action of air at common temperatures; it is acted on by nitric and hot sulphuric acids; and vapourizes in *vacuo* at common temperatures.— *Faraday, Brande's Jour.* x. 354.

Malleability of Solid Mercury.—During Capt. Parry's first voyage to the Arctic Regions, on February the 14th and 15th, (1820) the thermometer continued for 15 hours at from —54° to —55° F. Some mercury was frozen during the continuance of this cold weather, and beaten out on an anvil, previously reduced to the temperature of the atmosphere; it did not appear to be very malleable in this state, usually breaking after two or three blows from the hammer. This experiment was also tried some years since at Hudson's Bay. The mercury when frozen was reduced to sheets as thin as paper. And on plunging a mass of this frozen metal into a glass of warm water, the mercury became fluid and the water was immediately frozen. By the rapidity of the action the glass was shivered into a thousand pieces.

ADULTERATION. Mercury is sometimes adulterated with the alloy of lead and bismuth, a fraud which is easily detected by the want of its

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* From the latin word *Hydrargyrum.*

due fluidity, and by its not being perfectly volatile, but leaving a residuum when boiled in a platinum or iron spoon. The best method of purifying mercury is to re-distil it in an irom retort.—*See Ure's Chemical Dictionary*.

MERCURY AND OXYGEN.

Mercury is susceptible of two stages of oxidation, and both its oxides are capable of forming salts with acids.

Protoxide of Mercury.—Atom. Num. 208—*Symb.* O+Hg.

SYN. *Hydrargyri Oxidum Cinereum.*—U. S. Phar.

A black, insoluble, insipid powder ; best prepared by the process recommended by Donovan. This consists in mixing calomel briskly in a mortar with pure potassa in excess, so as to effect its decomposition as rapidly as possible. The protoxide is then to be washed with cold water, and dried spontaneously in a dark place. These precautions are rendered necessary by the tendency of the protoxide to resolve itself into the peroxide and metallic mercury, a change which is easily effected by heat, by the direct solar rays, and even by day-light. It is on this account very difficult to procure the protoxide of mercury in a state of absolute purity.—*Ann. of Phil.* xiv. 241, 321.

When mercury is agitated for a long time in contact with air it becomes converted into a black powder—to which Boerhaave gave the name of *Ethiops per se.* This was formerly supposed to be the protoxide, but, as pure mercury has a feeble attraction for oxygen, it is most probably, metallic mercury in a state of minute division, as is maintained by Berzelius. [*Traité de Chim.* iii. 107.] The same may be said of all the medicinal preparations formed by triturating metallic mercury with various viscous bodies, as oil, fat, gum, &c.

Peroxide of Mercury.—Atom. Num. 216—*Symb.* 2O+Hg.

SYN. *Hydrargyri Oxidum Rubrum.*—Lond. Phar.

PROPERTIES. This oxide is of a red colour, and sparingly soluble in water, forming a solution which has an acrid metallic taste, and communicates a green colour to the blue infusion of violets ; when heated to redness it is converted into metallic mercury and oxygen—and the same effect is said to be produced by long exposure to light.

PREPARATION. Peroxide of mercury may be formed either by the combined agency of heat and air, or by dissolving metallic mercury in nitric acid, and exposing the nitrate so formed to a temperature just sufficient for expelling the whole of the nitric acid. It is commonly known by the name of *Red Precipitate*.

REFERENCES. *Donovan on the Oxides and Salts of Mercury, Ann. of Phil.* xiv. 241. *Sefstrom and Thomson, same work,* xviii. 126. *Guibourt, Ann. de Chim. et de Phys.* i. 422, *who maintains that the Protoxide exists pure only in combination with Acids. On the methods of making various Mercurial Preparations, see the controversy between Dr. Hope and Mr. Phillips, in Ann. of Phil.* xvii. *and* xviii. *Berzelius, Traité de Chim.* iii. 103. *Carpenter on the division of Mercury by trituration, Sill. Jour.* xii. 173.

MERCURY AND CHLORINE.

Protochloride of Mercury.—Atom. Num. 235·45—Symb. Cl+Hg.

Syn. *Calomel.—Mild Muriate of Mercury, &c.*

Properties. This compound when obtained by sublimation, occurs in semi-transparent crystalline cakes; but, as formed by precipitation, is a white powder, having a density of 7·2; it is distinguished from the bichloride by not being poisonous, by having no taste, and being insoluble in water; it is but little affected by acids, but pure alkalies decompose it, separating the black protoxide of mercury; when mixed with lime-water it forms the substance called in medicine *Black Wash.*

Native state and preparation. This compound is a rare native production, called *Horn Quicksilver*, which occurs crystallized in quadrangular prisms, terminated by pyramids. It is always generated when chlorine comes in contact with mercury at common temperatures. It may be made by precipitation, by mixing muriatic acid or any soluble muriate with a solution of the protonitrate of mercury. It is more commonly prepared by sublimation. This is conveniently done by mixing 272 parts, or one proportion, of the bichloride with 200 parts, or one proportion, of mercury, until the metallic globules entirely disappear, and then subliming. When first prepared it is always mixed with some corrosive sublimate, and therefore should be reduced to powder and well washed before being employed for chemical and medical purposes.

References. *For details of the processes of Scheele, Chenevix and others, see Aikin's Chem. Dict. and Webster's Brande. Gray's Operative Chemist contains a description of Howard's plan for reducing Calomel to a fine powder. Whatton on the origin of the name of Calomel, Ann. of Phil.* xviii. 427.

Bichloride of Mercury.—Atom. Num. 270·9—Symb. 2Cl+Hg.

Syn. *Corrosive Sublimate.—Corrosive Muriate of Mercury.—Perchloride of Mercury.*

Properties. A white semi-transparent mass, sometimes perfectly crystallized—[*Ann. of Phil.* xxii. 285;] it has an acrid, burning taste, leaves a metallic flavour on the tongue, and in solution reddens litmus; its specific gravity is 5·2; it sublimes at a red heat without change; requires twenty times its weight of cold, and only twice its weight of boiling water for its solution, and is deposited from the latter as it cools in the form of prismatic crystals; is soluble also in ether and in strong alcohol; and from its watery solution alkalies throw down the red peroxide, that produced by lime-water, being called in medicine *Yellow Wash.*

It possesses acid properties.—It has been shown by Bonsdorf that corrosive sublimate possesses the characters of an acid and that it is capable of combining with other chlorides and with muriates. A class of compounds is thus formed to which he has given the name of *Chloro-hydrargyrates.* Dr. Thomson describes nineteen of these com-

pounds of which the *White Precipitated Mercury* is one.—*See Thomson's Inorg. Chem.*

PREPARATION. This chloride is formed by heating metallic mercury in chlorine gas. But it is prepared for medicinal purposes by subliming a mixture of the bipersulphate of mercury with the chloride of sodium, or sea-salt. The exact quantities required for mutual decomposition are 296 parts, or one proportion of the bipersulphate, and 120 parts, or two proportions of the chloride.

ACTION ON THE ANIMAL ECONOMY. The common appellation of this substance indicates its corrosive nature. It thus affects the throat, stomach and intestines, producing high inflammation and all its consequences—vomiting, dysentery, occasional inflammation of the lungs, or of the urinary passages. After death, greater or less marks, of corrosion, and combined sometimes with mortification, are noticed.

TESTS—*In the solid state.* 1. Corrosive sublimate sublimes in white acrid fumes on the application of heat. 2. Add to it the solution of the protochloride of tin, "corrosive sublimate, when left for some time in this solution, first becomes grayish-black, and in no long time its place is supplied by globules of mercury, the chlorine being entirely abstracted, by the protochloride, which consequently passes to the state of a bichloride." This is a beautiful test, for which we are indebted to Professor Christison.—*Treatise on Poisons.*

In the fluid state. 1. Sulphuretted hydrogen, in sufficient quantity, causes a black precipitate, the sulphuret of mercury. 2. The protochloride of tin is a very delicate test. It gives a white precipitate in small quantity, but which darkens as more is added. It may be continued until metallic mercury is thrown down, as in the previous experiment. 3. Nitrate of silver is a good test of the presence of chlorine, as it throws down a white precipitate, the chloride of silver. 4. Hydriodate of potash carefully added, causes a pale scarlet precipitate, the iodide of mercury. 5. Mr. Sylvester's reduction by means of galvanic electricity. Let a piece of gold be moistened with the solution, then touch it through the solution with a small iron wire, an amalgam will be formed on the gold in a few seconds. The mercury thus metallized may be sublimed by placing the gold, (if a ring or wire has been used) in a tube, and applying heat to the bottom.—*Orfila.*

REFERENCES. *For a detail of the processes adopted for preparing this compound, consult the general works quoted under the last article. Webster's Brande contains an interesting view of the changes which take place in the substances employed. Dr. Davy's experiments on the solibility of corrosive sublimate, and the action of light upon it and its solutions, in Phil. Trans.* 1822. *or Repert. of Arts,* 2d ser. xlii. 348. *On its poisonous effects, see Christison on Poisons ; Orfila, in Annales D'Hygiene,* i. 559 ; *and Beck's Medical Jurisprudence.*

MERCURY AND BROMINE.

Mercury and bromine combine in two proportions. The first compound is formed by the addition of an alkaline hydrobromate to the protonitrate of mercury. The second by bringing bromine and mer-

cury in contact—heat is evolved, but no light, and a white bromide is the result.

MERCURY AND IODINE.

There are at least two compounds of these bodies. The *Protiodide*, consisting of one proportion of mercury and one of iodine, is yellow, and is formed by mixing a solution of the protonitrate of mercury with the hydriodate of potassa. The *Deutiodide*, consisting of one proportion of mercury and two of iodine, is of a very rich red colour, and is formed by the action of hydriodate of potassa on any persalt of mercury. It forms a beautiful pigment.—*A. A. Hayes, Sill. Jour.* xvi. 174.—*On the medicinal employment of these compounds, see Magendie's Formulary.*

MERCURY AND SULPHUR.

By combination with sulphur, mercury forms two distinct compounds.

Protosulphuret of Mercury.—Atom. Num. 216—*Symb.* S+Hg.

A black-coloured substance which may be converted into the sulphate by digestion in nitric acid, and which, when exposed to heat, is resolved into the bisulphuret and metallic mercury.

It is prepared by transmitting a current of sulphuretted hydrogen gas through a dilute solution of the protonitrate of mercury, or through water in which calomel is suspended.

When equal parts of sulphur and mercury are triturated together until the metallic globules cease to be visible, a dark-coloured mass results, called *Ethiops Mineral*. It is the *Black Sulphuret of Mercury* of the Pharmacopeias, but Mr. Brande has proved it to be a mixture of sulphur and bisulphuret of mercury.—*Brande's Jour.* xviii. 294.

Bisulphuret of Mercury.—Atom. Num. 232—*Symb.* 2S+Hg.

A compound of a beautiful red colour, which when reduced to powder forms the well known pigment called *Vermilion.*

NATIVE STATE AND PREPARATION. This substance occurs native, and is known by the name of *Cinnabar*, from which most of the mercury of commerce is obtained by distillation with iron filings. This compound is artificially prepared by fusing sulphur with about six times its weight of mercury, and subliming in close vessels. It may also be obtained by mixing concentrated solutions of corrosive sublimate with hydro-sulphuret of ammonia. A brownish muddy precipitate is obtained, which, when left undisturbed, turns yellow in three or four days, then orange, and finally acquires a beautiful cinnabar colour.—*Nicholson's Jour.* 8vo. i. 299.

It has been shown by H. Rose, that sulphuret of mercury forms compounds in atomic proportions with the chloride, iodide, bromide and fluoride of that metal.—*Ann. de Chim. et de Phys.* xl. 46.

ADULTERATION. This compound is sometimes adulterated by red lead, chalk and dragon's blood. The former may be detected by exposing the suspected vermillion to heat in an iron spoon. Pure vermillion will volatilize without residue, but if it contains red lead it will

leave in the spoon a brown powder.   Chalk may be detected by mixing the suspected powder with a little water and adding nitric acid. Effervescence will be produced if any chalk is present, and the solution may be subsequently neutralized with ammonia and treated with oxalate of ammonia, by which the lime will be thrown down. If dragon's blood be present it may be detected by digesting the suspected vermilion in alcohol, when the solution will appear red.

REFERENCES. *Berzelius, Traité de Chim.* iii. 112. *Guibourt, Ann. de Chim. et de Phys.* ii. 425.   *The process used by the Dutch, so celebrated for the preparation of Cinnabar, is described in Ann. de Chim.* iv. *and Aikin's Chem. Dict.* ii.   *For the process of the Chinese, see Brewster's Edin. Jour. of Science, N. S.* ii. 352. *Kirchoff on the preparation of Cinnabar in the humid way, Repert. of Arts,* 2d ser. xlii. 180.

Bicyanide or Bicyanuret of Mercury.—Atom. Num. 252*—Symb.* $2(2C+N.)+Hg.$

PROPERTIES. This substance, when pure, is colourless and inodorous, has a very disagreeable metallic taste, and is highly poisonous ; it does not affect the colour of litmus or turmeric paper ; when strongly heated is converted into cyanogen and metallic mercury ; it is more soluble in hot than in cold water, and dissolves in that liquid without change ; the solution has not the characteristic odour of the salts of hydrocyanic acid, nor do alkalies throw down the oxide of mercury.

Action of Iron.—When iron is left in contact with a solution of bicyanuret of mercury water is decomposed ; its oxygen combines with the iron, and its hydrogen with the cyanogen, while the mercury is reduced to the metallic state.   This action, however, as Scheele has remarked, is slow, but it is instantaneous if a little sulphuric acid be added.—*Lond. and Edin. Phil. Mag.* vii. 78.

PREPARATION.   This compound is best prepared by boiling, in any convenient quantity of water, eight parts of finely levigated ferrocyanate of the peroxide of iron, quite pure and well dried on a sand bath, with eleven parts of the peroxide of mercury, in powder, until the blue colour of the ferrocyanate entirely disappears.   A colourless solution is formed, which, when filtered and concentrated by evaporation, yields crystals of bicyanuret of mercury, in the form of quadrangular prisms.   In this process, the oxygen of the oxide of mercury unites with the iron and hydrogen of the ferrocyanic acid ; while the metallic mercury enters into combination with the cyanogen.— *Turner, in the Edin. Jour. of Science,* v. 245. *Johnston on the constitution of Cyanide of Mercury, same work, N. S.* i. 119.

MERCURY AND THE METALS.

It has already been stated, that when mercury combines with other metals, the resulting compounds are called *amalgams,* (page 212) and some of these substances have been noticed.

A solid amalgam of lead and another of bismuth, on admixture together, have the singular property of instantly becoming fluid.   The amalgams of gold and silver are employed in gilding and plating ;

and the amalgam of tin and mercury is used in the manufacture of common mirrors.—*For a good description of this process, see Bigelow's Technology.*

Iron is not acted on by mercury ; and hence this last metal is usually kept in vessels of iron.

SALTS OF MERCURY.

Protonitrate of Mercury.—A white crystalline salt, which has a disagreeable taste, and is not altered by exposure to the air ; is only partially soluble in water, and the solution affords black precipitates, with the alkalies.

This salt is best formed by digesting mercury in nitric acid, diluted with three or four parts of water, until the acid is saturated, and then allowing the solution to evaporate spontaneously, in an open vessel. The solution always contains, at first, some nitrate of the peroxide, but if metallic mercury is left in the liquid, a pure protonitrate is gradually deposited.

Mitscherlich supposes this to be a subsalt, and obtains the neutral salt in crystals, by dissolving the former in pure water, acidulated with nitric acid, and evaporating spontaneously without the contact of metallic mercury or uncombined oxides.—*Ann. de Chim. et de Phys.* xxxv. 421.

Pernitrate of Mercury.—*Atom. Num.* 270—*Symb.* $(5O+N)+$ $(2O+Hg.)$

A beautiful transparent and colourless salt, which crystallizes in rhombic prisms ; when heated it becomes first opaque, then yellow, and is at last dissipated.

When this salt, which is obtained by heating mercury in an excess of strong nitric acid, is thrown into hot water it is resolved into a soluble salt, the composition of which is unknown, and into a yellow subsalt which is the *Nitrous turpeth* of the old writers. The latter was found by Grouvelle to consist of one proportion of acid to two of the peroxide. [*Ann. de Chim. et de Phys.* xix.] If this is correct, it is a *Dipernitrate of Mercury.*—See *Thomson's First Prin.* ii. 404.

Protosulphate of Mercury.—*Atom. Num.* 266—*Symb.* $(3O+S)+$ $(O+Hg.)+2$ aq.

A salt occurring in fine white scaly crystals, which have little taste, and redden vegetable blues. It is prepared by boiling mercury in its weight of sulphuric acid.—*Thomson's First Prin.* ii. 395.

Persulphate of Mercury.—*Atom. Num.* 305—*Symb.* 2 $(3O+S)+$ $(2O+Hg.)+9$ aq.

This salt is strictly *Bipersulphate*, and occurs in white irregular crystals. It is formed by heating for some time one part of mercury in three of sulphuric acid.

When this salt is thrown into hot water, a yellow precipitate, formerly called *Turpeth Mineral*, subsides. According to Dr. Thomson, this last is a true persulphate, consisting of one proportion of acid and

one of peroxide of mercury. [*First Prin.* ii. 403.] The hot water retains some of the sulphate in solution, together with free sulphuric acid.

The principal use of this salt is in the preparation of corrosive sublimate and calomel.

Protophosphate of Mercury.—A white tasteless powder, insoluble in water, formed by decomposing nitrate of mercury by phosphate of soda.

Protocarbonate of Mercury.—A white tasteless insoluble powder, obtained by precipitating a solution of nitrate of mercury by carbonate of soda.

Cyanite of Mercury? Fulminating Mercury.—A powerful detonating compound of mercury, described in the Philosophical Transactions for 1800, by Mr. E. Howard. It is prepare l by dissolving 100 grains of mercury in a measured ounce and a half of nitric acid, of specific gravity 1·3; and adding, when the solution has become cold, two ounces by measure of alcohol, the density of which is 0·849.— The mixture is then heated till a moderately brisk effervescence takes place, during which the fulminating compound is generated. The precipitate which falls down is to be immediatly collected on a filter, well washed with distilled water and dried in a heat not exceeding that of a water bath. This powder has the property of detonating loudly in a gentle heat, or by slight friction. It sometimes explodes from such trifling causes that it cannot be kept without danger, even when secured from friction or heat. [*See Henry's Chem.* ii. 140.] According to Liebig and Gay Lussac, this compound consists of oxide of mercury combined with a peculiar acid, which they named the *Fulminic;* but this is now generally believed to be identical with the cyanous acid of Wohler, and if this is correct, fulminating mercury is properly a cyanite of mercury.

Chromate and Bichromate of Mercury.—The former exists in a dull yellow powder, obtained by boiling a solution of ammonia on the bichromate; which is of a beautiful scarlet colour, and is obtained by adding chromate of potassa to the protonitrate of mercury. *See a valuable paper on the combinations of Chromium, by A. A. Hayes, in Silliman's Jour.* xiv. 136, *omitted under Chromium.*

REFERENCES. *On the Salts of Mercury, see Donovan's paper before quoted, and Thomson's First Prin.* ii. 359.

TESTS OF THE SALTS OF MERCURY. Some of these have already been noticed under corrosive sublimate. The soluble salts furnish white precipitates with ferrocyanate of potassa, and black with sulphuretted hydrogen. A plate of copper immersed into their solutions occasions the separation of metallic mercury. The insoluble salts are mostly entirely volatilized at a red heat; if distilled with charcoal, they afford metallic mercury.

SECTION XXXVI.

Silver.

Atom. Num. 108.—Symb. Ag.*—Sp. gr. 10·51.

PROPERTIES. This metal has a beautiful white colour and great lustre, being surpassed in this respect only by polished steel; its specific gravity when hammered, is 10·5, and in malleability and ductility it is only surpassed by gold; when pure is so soft that it may be cut with a knife; it fuses at the temperature of 20° or 22° of Wedgewood; is not oxidized by exposure to air or moisture, but when exposed in a state of fusion to a current of air or oxygen gas, a film of oxide is formed on the surface, but it parts with the oxygen spontaneously as it becomes solid, [*Lucas, in Manchester Memoirs, N. S.* iii.] a property which appears to belong only to pure silver. [*Chevillot, Ann. de Chim. et de Phys.* xiii. 299.] According to Gay Lussac, a more advantageous process is, to throw small quantities of nitre upon silver retained in fusion in a crucible. In about half an hour the crucible is to be withdrawn and plunged into water brought under a bell glass, when a large quantity of oxygen is disengaged.—*Jour. of the Royal Institution*, ii. 627.

NATIVE STATE AND EXTRACTION. This metal frequently occurs native in silver mines, both massive and in octahedral or cubic crystals. It is also found in combination with several other metals, such as gold, antimony, copper, and arsenic, and with sulphur. Seventeen different ores of silver are described by mineralogists.

Pure silver may be obtained for chemical purposes by placing a clean piece of copper in a solution of the nitrate of silver, washing the precipitated metal with pure water, and then digesting it in ammonia, in order to remove any adhering copper. It may also be prepared from the chloride of silver, either by exposing that compound mixed with a pure or carbonated alkali to a strong heat in a black lead crucible, or by transmitting over it a current of hydrogen gas, when heated to redness in a tube of porcelain.

TESTS OF PURE SILVER. Dissolve it in nitric acid. It must give no black insoluble precipitate, otherwise it contains gold. If it gives a blue solution it contains copper. The solution formed by dissolving *silver leaf* in nitric acid, must not become purple when mixed with a solution of chloride of gold, otherwise the silver leaf contains tin.

REFERENCES. *Donovan, in Phil. Mag.* xlvii. 205. *Thomson's First Prin.* ii. 436. *Gay Lussac on the precipitation of Silver by Copper, in Ann. de Chim. or Repert. of Arts,* 2d ser. xx. 252. *Berzelius, Traité de Chim.* iii. 88. *Del Rio on the reduction of Silver Ores by the method of Becquerel. Brewster's Edin. Jour. of Science, N. S.* v. 222.

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* From the latin word *Argentum.*

SILVER AND OXYGEN.

Oxide of Silver.—Atom. Num. 116— Symb. O+Ag.

This substance is of an olive colour, insoluble in water, and tasteless ; when heated the oxygen is driven off, and the metal is reduced. It is prepared by adding lime-water or solution of pure baryta to solution of nitrate of silver, washing and drying the precipitate.

When this oxide of silver, recently precipitated, is left in contact for ten or twelve hours with a strong solution of ammonia, the greater part is dissolved, but a black powder remains, which detonates violently from heat or percussion. It appears to be a compound of ammonia and the oxide of silver, or of nitrogen and silver. It should be made in very small quantities and dried spontaneously in the air. See *Berthollet, Ann. de Chim.* i.

When a solution of the oxide of silver in ammonia is exposed to the air, its surface becomes covered with a pellicle, which Mr. Faraday considers to be a distinct oxide with less oxygen than the one just described,—an opinion which is also confirmed by Dr. Thomson, who calls it a *suboxide.—Brande's Jour.* iv. 270. *Thomson's First Prin.* i. 433.

✠ SILVER AND CHLORINE.

Chloride of Silver.—Atom. Num. 143·45—Symb. Cl+Ag.

PROPERTIES. This compound when formed by precipitation is at first quite white, but by exposure to the direct solar rays, it becomes violet and almost black in the course of a few minutes, and a similar effect is produced by diffused day light ; it is insoluble in water and very sparingly dissolved by the stronger acids, but is soluble in ammonia ; at the temperature of about 500° it fuses, and forms a semi-transparent horny mass on cooling, and hence sometimes called *Horn Silver ;* bears the combined action of heat and charcoal without decomposition, but is readily decomposed by hydrogen gas, with the formation of muriatic acid ; it is also rapidly decomposed by tin and zinc.

It is decomposed by hydrogen gas.—If a few pieces of zinc be put into a test glass and some dilute sulphuric acid be poured over it, an effervesence takes place, and hydrogen gas is disengaged. Chloride of silver placed above the zinc in the same glass, is speedily reduced by this hydrogen and converted into metallic silver.

Effect of Light.—Pure chloride of silver is speedily changed from a pure white to a deep violet by exposure to light, Gay Lussac has however, ascertained that the presence of a very minute quantity of mercury prevents this chloride from being changed by the agency of light.

Chloride of silver sometimes occurs native in silver mines. It is always generated when silver is heated in chlorine gas, and may be prepared conveniently by mixing muriatic acid, or any soluble muriate with nitrate of silver.

REFERENCES. *On the composition of this substance, see Thomson's First Prin.* i. 429 ; *and Berzelius, in Ann. of Phil.* xv. 90. *Faraday on the*

✠ *test for silver*

decomposition of Chloride of Silver by Hydrogen and by Zinc, Brande's Jour. viii. 374.

SILVER AND BROMINE.

Bromide of Silver.—A light yellow curdy substance which blackens on exposure to light, is insoluble in water and in nitric acid, but soluble in ammonia. It is formed by adding an alkaline hydrobromate to a solution of nitrate of silver.

SILVER AND IODINE.

Iodide and Silver.—Atom. Num. 234—Symb. I+Ag.

A compound of a greenish yellow colour, insoluble both in water and ammonia, and formed by mixing hydriodate of potassa with nitrate of silver.

SILVER AND SULPHUR.

Sulphuret of Silver.—Atom. Num. 124—Symb. S+Ag.

A compound of a black colour, capable of being cut with a knife, much more fusible than the metal, and from which the sulphur can be driven off by heat.

This substance often occurs native in mines, and is the *Silver Glance* of mineralogists. It may be prepared by heating to low redness thin plates of silver with alternate layers of sulphur. It is also formed by transmitting a current of sulphuretted hydrogen gas through a solution of nitrate of silver.

Cyanide of Silver.—Atom. Num. 134—Symb. (N+2C)+Ag.

A white curdy substance, similar in appearance to the chloride of silver, insoluble in water and nitric acid, and soluble in a solution of ammonia ; is decomposed by muriatic acid, with formation of hydrocyanic acid and chloride of silver. It is formed by mixing hydrocyanic acid or an alkaline hydrocyanate with nitrate of silver.

SILVER AND THE METALS.

Some of the alloys of silver have been noticed ; but the most important is the alloy of silver and copper, as it constitutes plate and coin. The *standard silver* of Great Britain consists of 0·90 copper, and 11·10 silver. [*Henry.*] The standard silver of the United States consists of 1485 of fine silver and 179 parts of copper ; 13 Troy ounces of standard silver are coined into 15 dollars. This combination, though its colour differs but little from that of pure silver, is much harder, and is better adapted for the purposes of coin, and of domestic implements. The silver of commerce is composed of 37 parts of fine silver and 3 of copper.

Amalgam of silver is sometimes employed for *plating ;* it is applied to the surface of copper, and the mercury being evaporated by heat, the remaining silver is burnished.

The quantity of pure silver in any of these alloys is determined by the process called *cupellation.* This process consists in exposing to

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heat a clean piece of the alloy, of a given weight, wrapped up in a quantity of sheet lead. This is performed in a *cupel*, or shallow crucible made of bone earth, which must be previously heated. The whole is then placed under a muffle and heated to bright redness ; the metals melt, and, by the action of the air upon the hot surface, the lead and copper are oxidized and absorbed by the cupel, and a button of pure silver ultimately remains.

REFERENCES. *The article Assay, in Aikin's Chem. Dict. Gray's Operative Chemist. Bigelow's Technology. Oersted on determining the composition of Alloys of Silver, &c. by the Magnetic Needle, Ann. de Chim. et de Phys. Nov.* 1828. *For an analysis of different European Silver coins, see Thomson's Inorg. Chem.* i. 638.

SALTS OF SILVER.

Nitrate of Silver.—Atom. Num. 170—*Symb.*—(5O+N)+(O+Ag.)

PROPERTIES. This salt is crystalline, colourless, bitter and very caustic ; it deliquesces by exposure to air ; is soluble in its own weight of cold, and in half its weight of hot water, and in about four times its weight of alcohol ; it undergoes igneous fusion, when heated, and assumes, on cooling, the appearance of a gray crystalline mass ; at a red heat it is completely decomposed, and metallic silver remains ; its solution produces a black stain upon the skin, and is indelible or peels off with the cuticle ; it may be decomposed by carbon, phosphorus and some of the metals.

It is decomposed by some of the combustibles.—A clean piece of phosphorus introduced into a solution of nitrate of silver, becomes covered with a crust of metallic silver. This reduction is also effected by a clean plate of copper, and by mercury. In the latter case the precipitation is slow, and produces a peculiar symmetrical arrangement, called the *Arbor Dianæ.*

PREPARATION. This salt is prepared by dissolving pure silver in nitric acid, diluted with from two to four parts of water, and evaporating the solution.

USES. Nitrate of silver, when fused and poured in this state into heated moulds, forms the common *Lunar Caustic,* or *Lapis Infernalis,* employed by surgeons as a cautery. It is also the basis of the *Indelible Ink,* used for marking linen and cotton, and is sometimes employed for giving a black colour to the hair, but for this purpose it should be used with caution. In the laboratory it is used as a test of chlorine and muriatic acid.*

REFERENCES. *Bradenbourg on making pure Nitrate of Silver from an Alloy of Silver and Copper, Ann. of Phil.* xv. 389. *For the mode of*

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* The following singular fact is stated by Sir John Herschel in his Discourse on the Study of Natural Philosophy. A solution of nitrate of silver and another of hyposulphite of soda, have each of them separately, when taken into the mouth, a disgusting bitter taste ; but if they be mixed, or if one be tasted before the mouth is thoroughly cleared of the other, the sensible impression is that of intense sweetness.

obtaining Arbor Dianæ, see Webster's Brande ; and for another process, which consists in suspending a small knot of fine linen containing Quicksilver, in the Nitric Solution of Mercury and Silver, see Repert. of Arts, 2d ser. xvii. 381. *For a notice of the method of copying engravings, &c. by Nitrate of Silver, by T. Wedgewood, see Paris' Life of Davy,* i. 161.

Fulminating Silver.—Besides the fulminating compound of silver, formed by the addition of ammonia to the nitrate of silver, another one is formed, by a process similar to that noticed under fulminating mercury, viz. by adding alcohol to a solution of silver in nitric acid. Its preparation requires great caution. The same views are entertained concerning its composition as concerning that of fulminating mercury. It is probably a *Cyanite of Silver.—For details concerning its preparation, &c. see Henry's Chem. or Webster's Brande ; and for some new views concerning it, see Dr. Ellet's Essay upon the compounds of Cyanogen, Sill. Jour.* xviii. 335. *See also a Report on the Fulminating Powders, capable of being used as Priming for Fire Arms, by MM. Aubert, Pelissier and Gay Lussac, in which the preference is given to Fulminating Mercury, Ann. de Chim.* xlii. *or Repert. of Pat. Invent.* ix. 182, 307.

Sulphate of Silver.—Atom. Num. 156—*Symb.* $(3O+S)+(O+Ag.)$

PROPERTIES. A white powder with a metallic taste; when heated it melts and is decomposed, being changed into sulphurous acid, oxygen and metallic silver; soluble in about 88 times its weight of boiling water, and when the solution cools, the salt is partly deposited in the state of small needles.— *Thomson's First Prin.* ii. 406.

This salt may be obtained by digesting sulphuric acid over oxide of silver, or by mixing together concentrated solutions of nitrate of silver and sulphate soda. It is the proper test for ascertaining the presence of muriatic acid where sulphuric acid is also supposed to be present, for the nitrate of silver precipitates both these acids.

There is also a *Hyposulphite* and a *Sulphite of Silver,* obtained by processes similar to those already described.

• *Phosphate of Silver.*—This salt is obtained by adding solution of phosphate of soda to solution of pure nitrate of silver, washing and drying the precipitate. It is in the form of a yellow powder, fusible at a red heat without any farther loss of weight. It appears to be a subphosphate.— *Thomson's First Prin.* ii. 408.

Carbonate of Silver.—Atom. Num. 138—*Symb.* $(2O+C)+(O+Ag.)$

A white insoluble powder, with a slight shade of blue, which blackens by exposure to light, and effervesces with dilute nitric acid. It is formed by adding carbonate of potassa to nitrate of silver. Carbonate of ammonia only throws down a portion of the silver from the nitrate, and forms a triple *Ammonio-Carbonate of Silver.*

Chromate of Silver, is precipitated of a crimson colour by adding chromate of soda to nitrate of silver. It soon loses its brilliant tint and becomes brown.—*Phil. Mag. and Ann.* i. 345.

Bichromate of Silver, may be obtained in dark crimson coloured crystals by adding liquid sulphuric acid to a solution of the bichro-

mate of potassa and immersing a clean plate of silver into it, or by mixing the solutions in a silver capsule.

REFERENCES. *On the Salts of Silver, see Thomson's First Prin.* ii. 404. *Proust's facts relating to the Chemical history of Silver, Jour. de Phys. or Repert. of Arts,* 2d *ser.* ix. 310, 355.

TESTS OF THE SALTS OF SILVER. Those which are soluble are recognized by furnishing a white precipitate with muriatic acid, which blackens by exposure to light, and which is readily soluble in ammonia, and by affording metallic silver upon the immersion of a plate of copper. The salts insoluble in water are soluble in liquid ammonia, and when heated on charcoal, before the blow-pipe, they afford a globule of silver

SECTION XXXVI.

GOLD.

Atom. Num. 200—*Symb.* Au.* *Sp. gr.* 19·3.

PROPERTIES. This metal, whose history and principal uses are similar to those of silver, has an orange-yellow or reddish-yellow colour, and may be made to assume a high lustre, only inferior to steel, silver and mercury ; exceeds all other metals in malleability and ductility, but is less tenacious than several other metals ; is not changed by exposure to air and moisture for any length of time, nor oxidized by being kept in a state of fusion in open vessels ; it is not acted on by any of the pure acids, however concentrated, its only solvents being chlorine and nitro-muriatic acid ; the effect being in both cases ascribed to the agency of chlorine, it is exceedingly soft and flexible when pure ; is less fusible than silver, requiring a heat of 32° of Wedgewood for its fusion.

NATIVE STATE AND PREPARATION. Gold occurs in nature in a metallic state, either pure or in combination with other metals. It occurs massive, capillary, in grains, and crystallized in cubes and octahedrons. It is most frequently found in alluvial soils and in the beds of certain rivers, especially those of the west coast of Africa and Peru, Brazil and Mexico. It is also found in various parts of Europe and of North America, especially in North Carolina.

This metal may be obtained pure by dissolving standard gold in nitro-muriatic acid, evaporating the solution to dryness, redissolving the dry mass in distilled water, filtering and adding to it a solution of protosulphuret of iron ; a black powder falls, which, after having been washed with dilute muriatic acid and distilled water, affords on fusion a button of pure gold.—*Vauquelin.*

REFERENCES. *Olmstead's account of the Gold Mines of North Carolina. Sill. Jour.* ix. 5 ; *and for other localities see Cleaveland's Mineralogy.*

* From the latin *Aurum.*

GOLD AND OXYGEN.

Oxides of Gold.

There is still much uncertainty concerning the compounds of gold and oxygen. Berzelius is of opinion that there are three, but their composition is not yet understood. The only well known oxide is that which is supposed to exist in the solution of gold, combined with muriatic acid. According to M. Pelletier, the best method of forming it is by digesting the muriate with pure magnesia, washing the precipitate with water, and removing the excess of magnesia by dilute nitric acid. This is probably a peroxide, consisting of three atoms of oxygen and one atom of gold.—*Berzelius, Javal,* and *Thomson.*

The *Peroxide of Gold* is yellow in the state of hydrate, and nearly black when pure ; is insoluble in water, and completely decomposed by solar light or a red heat ; it is readily soluble in muriatic acid, yielding the common solution of gold, but it forms no definite compound with any acid which contains oxygen ; it has a very feeble affinity for nitric and sulphuric acids, but combines, on the contrary, with alkaline bases, such as potassa and baryta, apparently forming regular salts, in which it acts the part of a weak acid. Hence Pelletier proposes the term *Auric Acid* for the peroxide of gold, and to its compounds with the alkalies he gives the denomination of *Aurates.*

Fulminating Gold.—The peroxide of gold is thrown down of a yellow colour, by ammonia, and the precipitate is an aurate of that alkali. It is a highly detonating compound, analogous to the fulminating silver described in the last section.

REFERENCES. *Proust's facts relating to the chemical history of Gold, Jour. de Phys. or Repert. of Arts,* 2d *ser.* ix. 289, 350. *Pelletier, Ann. de Chim. et de Phys.* xv. *or Brande's Jour.* x. 117. *Vauquelin's experiments on some preparations of Gold, Ann. de Chim. and Repert. of Arts,* 2d *ser.* xx. 243. *Oberkampf's memoir on various combinations of Gold, Ann. de Chim.* lxxx., *or Repert. of Arts,* 2d *ser.* xxi. 181, 249. *Berzelius, Traité de Chim.* iii. 1. *Javal, Ann. de Chim. et de Phys.* xvii. 337, *or Brande's Jour.* xii. 318. *Thomson, in First Prin. and Phil. Mag. and Ann.* vii. 460.

GOLD AND CHLORINE.

The same degree of uncertainty exists with regard to the chlorides, as to the oxides of gold. Gold leaf introduced into chlorine gas takes fire and burns ; and if it be suspended in water, into which the gas is passed, it is dissolved, and the solution may be concentrated by evaporation. The solution obtained in the manner directed in the last article, consists also, most probably, of the same *Perchloride.* By exposure to moderate heat, it parts with two-thirds of its chlorine, and is converted into a yellow insoluble *Protochloride.*

Chloride of gold is capable of combining with other chlorides. The resulting compounds are called *Chloroaurates,* and have been examined by Bonsdorf.—*See Thomson's Inorg. Chem.* ii. 831.

The solution of gold is decomposed by substances which have a strong affinity for oxygen. On adding protosulphuret of iron, dis-

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solved in water, the iron is oxidized to a maximum, and a copious brown precipitate subsides, which is metallic gold in a state of perfect purity. A similar reduction is effected by most of the metals, and by sulphurous and phosphorous acids. So when a piece of charcoal is immersed in the solution of gold, and exposed to the direct solar rays, its surface acquires a coating of metallic gold ; and ribands may be gilded by moistening them with a dilute solution of gold, and exposing them to a current of hydrogen or phosphuretted hydrogen gas.

When a strong aqueous solution of gold is shaken in a phial with an equal volume of pure ether, two fluids result, the lighter of which is an *Etherial Solution of Gold*. This solution, which is used for gilding a number of substances, should be decanted immediately and kept in a stopped bottle enclosed in a case to protect it from the action of light.

When the protomuriate of tin is added to a dilute aqueous solution of gold, a purple coloured precipitate, called the *Purple of Cassius*, is thrown down, which is the substance employed in painting on porcelain for giving a pink colour. It appears to be a compound of the peroxide of tin and the purple oxide of gold, in which the former is supposed to act as an acid.

REFERENCES. *For experiments on the revival of Gold, see Mrs. Fulhame on Combustion, and Count Runford's paper in Phil. Trans. for 1798, 449, or his Essays. Dr. Clarke on the Purple of Cassius, Ann. of Phil.* xvii. 393, *and also the papers of Proust and Oberkampf, quoted under the last article. Johnston on the double Chlorides of Gold, Brewster's Edin. Jour. N. S.* iii. 131, 290.

Bromide of Gold.—Balard observed the solubility of gold in bromine ; and Lampadius found that the dry compound is constituted of equal parts of gold and bromine. It is of a grayish black colour, is soluble in water, and gives a deep-red liquid, which yields crystallized hydrobromate of gold by evaporation. The colour of this salt is so intense, that a single grain communicates a perceptible tint to 5,000 grains of water.—*Brande's Jour. N. S.* iii. 489.

Iodide of Gold, may be obtained by acting on oxide of gold with hydriodic acid, or by mixing chloride of gold with hydriodate of potassa, and washing and drying the precipitate. It is insoluble in cold water, and very sparingly soluble in hot. It is decomposed by heated nitric or sulphuric acids, which reduce the gold and set iodine at liberty. It consists, according to Pelletier, of one proportion of each of its elements.

Sulphuret of Gold.—Sulphur, even when assisted by heat, has no action on gold ; but when a current of sulphuretted hydrogen is passed through a solution of that metal, a black precipitate is formed, which is a true sulphuret of gold. The sulphur may be easily expelled from this combination by heat. It appears to be composed of one proportion of gold and three proportions of sulphur.

Phosphuret of Gold.—This compound may be obtained by passing a stream of phosphuretted hydrogen through a solution of gold. It has a gray colour and metallic lustre.

GOLD AND THE METALS.

Gold combines with most of the metals.   Antimony, tin, zinc and lead, when alloyed with gold, destroy or impair its malleability.   It is stated that even the fumes of antimony in the neighborhood of melted gold, are sufficient for this purpose.

With copper, (standard gold,) the alloy is perfectly ductile and malleable, but harder than pure gold, and resists wear better than any alloy except that with silver.   The sterling or standard gold of Great Britain, consists of gold alloyed with one-twelfth its weighs of copper, or a mixture of both, as is most common, and according to Mr. Hatchett, the average of its specific gravity is 17·5.   The standard gold of the United States consists of nearly the same proportions of gold and alloy.   (For a table of the specific gravity of various gold pieces, see *Hatchett's paper*, or *Thomson's Inorg. Chem.*)

The degree of purity of gold is expressed by the number of parts contained in 24 parts of any mixture.   Thus gold, in which 24 such parts, (termed *carats*) contains 22 of the pure metal, is said to be 22 carats fine.   Absolutely pure gold, using the same language, is 24 carats fine; and gold alloyed with an equal weight of another metal, 12 carats fine.

The process of *water gilding* consists in applying an amalgam of gold to the surface of silver, and driving off the mercury by heat.   In gilding porcelain, *Gold Powder*, obtained by the decomposition of the chloride, is commonly employed.   It is applied with a pencil, and burnished after having been exposed to the heat of a porcelain furnace.

REFERENCES. *Aikin's Dict. art. Gold, contains an account of the methods of purifying gold, &c. Lewis' Philosophical Commerce of the Arts. Hatchett on the various alloys, specific gravity and comparative wear of Gold, Phil. Trans.* 1803, *abridged in Repert. of Arts,* 2d ser. iv. 12. *The art. Gilding, in Edin. Encyclopedia. The art. Coinage, by R. Mushet, in Sup. to the Ency. Britannica. Bigelow's Technology. For a minute account of the mode of making gold leaf and gilt wire, see Reaumur's Mem. Paris,* 1713, p. 199, *and Lewis' Philosophical Commerce.*

SECTION XXXVII.

PLATINUM.

Atom. Num. 98·6.—*Symb.* Pt.—*Sp. gr.* 21·5.

This valuable metal, discovered by Wood in 1741, is found in various parts of South America, in the form of rounded or flattened grains, mixed with sand and other alluvial depositions; and in the province of Antioquia, in veins associated with gold. Rich mines of gold and platinum have also been recently discovered in the Uralian mountains. —*Edin. Jour. of Science,* v.

PROPERTIES. Pure platinum has a white colour very much like silver, but of inferior lustre; it is the heaviest of known metals; its mal-

leability is considerable, though far less than gold and silver; it may be drawn into wires, the diameter of which does not exceed the 2000th part of an inch; it is a soft metal, and, like iron, admits of being welded at a high temperature; it is a less perfect conductor of caloric than most other metals; it undergoes no change from the combined agency of heat and air, and may be exposed to the strongest heat of a smith's forge without being oxidated or fused; is not attacked by any of the pure acids, its only solvent being chlorine and nitromuriatic acid.

REFERENCES. *Dr. Wollaston's process for obtaining pure Platinum, rendering it malleable, &c. Phil. Trans. 1829, or Franklin's Jour. N. S. iv. 226. For a notice of the Gold and Platinum district in Russia, see the Jour. of the Royal Institution, i. 418. Coinage, &c. of Russian Platinum, Edin. New Phil. Jour. iii. 276, vi. 197. The Russian Method of rendering platinum malleable is described by W. Marshall in the Repertory of Patent Inventions, xiii. 397.*

PLATINUM AND OXYGEN.

According to Berzelius, there are two oxides of platinum, the oxygen of which is in the ratios of 1 to 2. The *protoxide* is of a black colour, reduced by a red heat, and prepared by the action of potassa on the protochloride of platinum. It probably consists of one atom of oxygen and one of platinum. The *peroxide* has not been obtained pure, but is supposed by Berzelius to exist in the muriate of platinum combined with muriatic acid.

Dr. Davy has described a third oxide, intermediate between the peroxide and the protoxide, [*Phil. Trans. for* 1820,] and Mr. Copper has also described what he calls a *Suboxide*, [*Brande's Jour.* iii. 119,] but this cannot be regarded as a definite compound.

PLATINUM AND CHLORINE.

Perchloride of Platinum is procured by evaporating the solution of platinum in nitro-muriatic acid, to dryness at a gentle heat. It is deliquescent, and is soluble in water, alcohol and ether. The ethereal solution is decomposed by the agency of light, metallic platinum being deposited.

The chloride probably consists of one proportion of platinum and two proportions of chlorine. When strongly heated it is converted into the *Protochloride*.

The chlorides of platinum combine with other chlorides and with the muriate of ammonia and form a class of compounds called *Chloroplatinates*, which have been investigated by Bonsdorf.—[See *Thomson's Inorg. Chem.* ii. 833.]—When a solution of sal-ammoniac is added to a liquid chloride of platinum, a beautiful orange-yellow precipitate falls, consisting of one atom of the bichloride of platinum+one atom muriate of ammonia. When this compound, which is commonly called the *muriate* of *platinum* and *ammonia*, is heated to redness, chlorine and muriate of ammonia are evolved, and pure platinum remains in the form of a delicate spongy mass, which causes a jet of hydrogen to inflame, and which kindles an explosive mixture of hydrogen and oxygen gases. Various contrivances for the purpose of producing instantaneous light, upon this principle, are now adopt-

ed. Dr. Hare states that if asbestos or charcoal be soaked under an exhausted receiver in muriate of platinum, then dried in an evaporating oven for twenty-four hours, and afterwards ignited, the property of ignition in the gaseous elements of water is acquired.—*Silliman's Jour.* xx. 160.

The *Bichloro-platinate of Potassium*, is obtained by adding pure potassa or a salt of potassa to a concentrated solution of chloride of platinum. It consists of very small octahedrons, very little soluble in water and not at all in alcohol. When heated it gives out chlorine and leaves a mixture of platinum and chloride of potassium. The property of forming this compound with potassa distinguishes platinum from all other substances.

PLATINUM AND SULPHUR.

Sulphuret of Platinum.—When sulphuretted hydrogen gas is transmitted through a solution of muriate of platinum, a black precipitate is thrown down, which Vauquelin regards as a hydrosulphuret of the oxide of platinum. It absorbs oxygen from the air while in a moist state, giving rise to the formation of sulphuric acid. Its composition has not been determined with accuracy.

A black sulphuret of platinum was procured by Mr. E. Davy, by heating the metal with sulphur; and Vauquelin obtained a similar compound by igniting the yellow muriate of platinum and ammonia, with twice its weight of sulphur. According to the analysis of these chemists, it contains about 16 per cent. of sulphur.—*Turner.*

Sulphate of Platinum.—The hydrosulphuret of platinum is converted by the action of nitric acid into a sulphate which possesses remarkable properties. On boiling it in strong alcohol, a black powder is precipitated, which consists, according to Mr. E. Davy, of 96 per cent. of platinum, together with a little oxygen, nitrous acid, and carbon, the last of which is supposed to be accidental. When this powder is placed on bibulous paper moistened with alcohol, a strong action accompanied with a hissing noise ensues, and the powder becomes red hot, and continues so until the alcohol is consumed. The substance which remains is pure platinum.—*E. Davy, Phil. Trans.* 1820.

Fulminating Platinum may be prepared by the action of ammonia in slight excess on a solution of sulphate of platinum. It is analogous to the detonating compounds which ammonia forms with the oxides of gold and silver.—*E. Davy, in Phil. Trans.* 1817.

PLATINUM AND THE METALS.

Platinum combines with other metals and forms alloys which are not in general characterized by useful properties. Its affinity for lead is strikingly shown by the following experiment: If a piece of lead foil, and another of platinum foil, of equal dimensions, be rolled up together, and the flame of a candle be cautiously directed by a blowpipe towards the edges of the rolls, at about a red heat, the two metals will combine with a sort of explosive force, scattering their melted particles and emitting light and heat in a surprising manner. [*Ann. of Phil.* xiv. 230.] A small bit of tin, zinc or antimony, rolled in platinum leaf, and treated in like manner, exhibits similar phenomena.—

[*Henry*, ii. 172.]   When alloyed with the more oxidable metals, it is remarkable that platinum becomes soluble in nitric acid, which has no action on the pure metal.

SECTION XXXVIII.

Palladium.

Atom. Num. 53—*Symb.* Pd.—*Sp. gr.* 11·5.

This metal was discovered by Dr. Wollaston in 1803, in an ore of platinum.

Properties.   Palladium resembles platinum in colour and lustre; it is both malleable and ductile; is harder than wrought iron; its point of fusion is intermediate between gold and platinum; is dissipated in sparks when intensely heated by the compound blow-pipe; it is oxidized and dissolved by nitric acid, and by the aid of heat is also acted on by sulphuric and muriatic acids, though its proper solvent is the nitro-muriatic.

This metal is obtained by adding to a neutral solution of the ore of platinum, a solution of bycyanide of mercury; and heating to redness the yellowish white flocculent precipitate of cyanide of palladium, which is gradually deposited.

Oxide of Palladium.—*Atom. Num.* 61—*Symb.* O+Pd.

When potassa is added to solution of palladium, an orange-coloured hydrate is thrown down, which becomes black when dried, and is decomposed by a red heat.   This oxide forms beautiful red coloured salts, from which metallic palladium is precipitated by protosulphate of iron, and by all the metals described in the foregoing sections, except ing silver, gold and platinum.

Berzelius describes two oxides of palladium, and a sulphuret, phosphuret and carburet.— *Traité de Chim.* iii. 75.

References.   *Wollaston, in Phil. Trans.* 1804. *and* 1805.   *Vauquelin's Memoir on Palladium and Rhodium, Ann. de Chim.* lxxxviii. 167; *or Ann. of Phil.* iv. 216.

SECTION XXXIX.

Rhodium.

Atom. Num. 52— *Symb.* R.—*Sp. gr.* 11.

This metal, discovered by Dr. Wollaston about the same time as the last, has only been procured in very minute quantities from the solutions of crude platinum, in the form of a black powder, which requires the strongest heat of a wind furnace for its fusion, and when fused has a white colour and metallic lustre; it is hard and brittle, and its specific gravity is about 11; in its pure state is not attacked by

any of the acids, but when alloyed with other metals, is oxidized and dissolved by the nitro-muriatic acid ; it is oxidized by ignition with nitre.

Oxides of Rhodium.—Two compounds of rhodium and oxygen are described. The *Protoxide*, consisting of one atom of each of the elements is black. The *Peroxide*, which is the basis of the salts of rhodium, is of a yellow colour ; and all these salts are either red or yellow, and the muriate is a rose red.— *See the references under the last Section.*

SECTION XL.

OSMIUM.

Atom. Num. 99 ?—*Symb.* Os. *Sp. gr.* 10.

This metal was discovered by Mr. Tennant in 1803, in a black pow-powder left after the digestion of crude platinum in nitro-muriatic acid. Osmium is separated from the iridium which this powder also contains, by alternate and frequent digestions in soda and muriatic acid. It can only be obtained as a metal in a disintegrated state ; it is capable of supporting a white heat, without being volatilized or fused ; it is of a dark gray or blue colour ; if ignited in open vessels, with access of air, it is oxidized and then dissipated in vapour. On agitating the metal with mercury, an amalgam is formed, and with copper, silver and gold, it forms malleable alloys.

The pure *Oxide of Osmium* is soluble in water and volatile ; it emits a peculiar odour, which has something of the pungency of chlorine. The aqueous solution is colourless, and when shaken with mercury, is decomposed, soon loses its smell and forms an amalgam.

Berzelius has recently examined this metal and its compounds—and has described five oxides and sulphurets and four chlorides.

SECTION XLI.

IRIDIUM.

Atom. Num. 98·6—*Symb.* Ir. *Sp. gr.* 18·68.

This metal was discovered by Mr. Tennant at the same time with the last. It is the most infusible metal known, having only been fused by the large galvanic battery of Mr. Children ; when it appeared as a globule of a brilliant white colour, and metallic lustre ; is attacked with great difficulty by nitro-muriatic acid, but is oxidized when heated with nitre.

Oxides.—The solution of the oxides of iridium in muriatic acid is, when first prepared, of a blue colour ; it afterwards becomes of an olive green, and subsequently acquires a deep red tint. These changes are attributed to its passing through different stages of oxidation.

Berzelius has lately ascertained that this metal is capable of forming four oxides and four chlorides.

The *Muriate of Iridium*, when deprived of its excess of acid, by heat, may be obtained in crystals of a deep brown colour, by evaporation. This salt, when dissolved in water, forms a red coloured solution, which is rendered colourless by pure alkalies or alkaline earths, by sulphuretted hydrogen, infusion of galls, or by ferrocyanate of potassa. It is decomposed by nearly all the metals, except gold and platinum, the iridium being thrown down in a metallic state. Iridium may also be obtained from the muriate, by exposing that salt to a red heat.

REFERENCES. *On the two last Metals, see Tennant, in Phil. Trans. for* 1804. *Vauquelin's Memoir on Iridium and Osmium, Ann. de Chim.* lxxxix. 150, *or Ann. of Phil.* vi. 433. *Wollaston, in Phil. Trans.* 1829. *Berzelius, Traité de Chim.* iii. 24.

CHAPTER IX.

VEGETABLE SUBSTANCES.

All bodies which are of vegetable origin are termed vegetable sub-stances. Oxygen, hydrogen and carbon are their principal ingredi-ents, with which a certain portion of nitrogen is sometimes united ; and variations in the proportions and mode of combination of these elements, occasion the great diversity which exists among the pro-ducts of the vegetable kingdom.

Every distinct compound which exists ready formed in plants, is called a *proximate or immediate principle*. Thus sugar, starch and gum are proximate principles. Opium, though obtained from a plant, is not a proximate principle, but consists of several proximate princi-ples, mixed more or less intimately with one another. The *proximate analysis* of vegetables consist in the separation of these distinct prin-ciples ; but the reduction of the proximate principles into their simp-lest parts, constitutes their *ultimate analysis*.

The proximate analysis of vegetables varies considerably with the nature of the substance to be separated ; and some of these processes will be hereafter noticed. The ultimate analysis consist in the de-composition of the body by heat, in contact with some other sub-stance, but it constitutes in its details one of the most delicate opera-tions of analytical chemistry. For the purpose of effecting this ob-ject several processes have been devised. That which is at present most highly approved was proposed by Gay Lussac and Thenard, and consists in mixing three or four grains of the substance to be ana-lyzed with about two hundred grains of the peroxide of copper, heating the mixture to redness in a glass tube, and collecting the gaseous products in a graduated glass jar, over mercury.—*For the details of this process, and the manipulations necessary, the reader is referred to the works of Thenard, Thomson, Henry or Berzelius. See also, Gay Lussac and Thenard's Physico-Chem. Researches, ii. ; Proust's observa-tions on the analysis of Organic Substances, Ann. of Phil. vi. 269, vii. 111; and his memoirs on the ultimate composition of Simple Alimentary Substances, &c., Phil. Trans. for 1827, or Phil. Mag. and Ann. iii. 31 and 98.*

Vegetable substances, and indeed all organic products, are charac-terized as follows :

1. They are composed of the same elements.

2. They are easily decomposed, both spontaneously and by art.

3. They cannot be formed by the direct union of their principles.

4. They are decomposed at a red heat, and often below it.— *Tur-ner*.

In the present state of our knowledge, vegetable bodies cannot be classified in a purely scientific manner. I shall notice them nearly in

the order proposed by Dr. Turner, on the basis of the general laws deduced by Gay Lussac and Thenard, viz:

1. Salifying principles or acids.

2. Salifiable principles or alkalies, and the substances related to them.

3. Substances which, in relation to oxygen, contain an excess of hydrogen.

4. Substances, the oxygen and hydrogen of which are in exact proportions for forming water.

5. Substances which, so far as is known, do not belong to either of the preceding sections.

SECTION I.

VEGETABLE SALIFYING PRINCIPLES OR ACIDS.

These substances are characterized by their having a sour taste, and changing the blue of litmus to red, but more especially by their power of combining with salifiable bases. Like all organic principles, they are decomposed by a red heat; though they are in general less liable to spontaneous decomposition than other vegetable substances. They are all colourless, and, with a single exception, solid; and are nearly all decomposed by hot nitric acid, by which they are converted into carbonic acid and water.

Some of the vegetable acids are the products of nature alone; some are the products of both nature and art; and some are exclusively the products of art. I shall present the prominent characters of most of these acids, noticing in detail only the most important.

Acetic Acid.—Atom. Num. 51—*Symb.* $3O+3H+4C$.

NATIVE STATE AND PROPERTIES. This acid exists in the sap of almost all plants, either free or combined with potassa or lime, and is also abundantly the product of art. It is transparent, colourless, and very volatile; has a pungent odour, very sour taste, and reddens litmus powerfully; in its most concentrated form it crystallizes when exposed to a low temperature, retaining its solidity until the thermometer rises to 50° F. It has a specific gravity varying from 1·056 to 1·08.

PREPARATION. Acetic acid may be obtained by the distillation of common vinegar, which is prepared by exposing malt or vinous liquors to the free access of atmospheric air, at a temperature slightly elevated; by the purification of pyroligneous acid procured from the distillation of wood; or still better, by the decomposition of the acetates.

The distillation of vinegar is effected in the same manner as that of water. The acid thus obtained is called *Distilled Vinegar*, and was formerly named *Acetous Acid*, upon the erroneous supposition that it was chemically different from strong acetic acid.

Concentrated acetic acid is best prepared by the decomposition of the acetate of soda by sulphuric acid, and subsequent distillation; or by subjecting the acetate of copper to heat. The acid, when first col-

lected, has a greenish tint, owing to the presence of copper, from which it is freed by a second distillation.

In addition to the above process may be mentioned, the exposure of common vinegar to low degrees of temperature, by means of which the water is frozen, and a concentrated acid remains in a liquid state.

Pyroligneous Acid.—The acid known under this name is an impure acetic acid prepared by the distillation of wood. When first made, it is of a dark colour, holding in solution tar and volatile oil, from which it is freed by mixing it with chalk, decomposing the resulting acetate of lime by digestion with sulphate of soda ; fusing the acetate of soda thus formed at a high temperature, insufficient to decompose the salt, but sufficient to expel or char the impurities ; and finally decomposing the acetate of soda by sulphuric acid.

Kreosote.

Mr. Reichenbach has recently obtained from pyroligneous acid and also from the tarry matter which distils over with the acid, a new substance which he calls *Kreosote*, from the Greek words meaning *flesh*, I *save.* This substance is highly interesting, not only on account of its chemical properties, but from its useful applications to therapeutics, domestic economy and the preservation of provisions for long voyages.

Kreosote is an oily, colourless liquid, possessing great refrangibility ; has a penetrating, disagreeable odour, similar to that of smoked beef : sp. gr. about 1·037 at 68° F., boils at 397° F., and is not congealed at a temperature of 16·6° F. ; burns with a smoky flame ; combines readily with acetic acid, water, alcohol, ether and with the alkalies ; it also coagulates albumen.

Antiseptic properties of Kreosote.—When fresh meat is put into a solution of kreosote, allowed to remain for half an hour or an hour, withdrawn, and afterwards dried, it may be exposed to the heat of the sun without putrifying, and in the space of eight days it becomes hard, the colour changes to a reddish-brown, and the flavour is that of good smoked beef. Fish may also be preserved by it.

Action on the Animal Economy.—When kreosote is placed upon the tongue, it occasions violent pain, and when poured in a concentrated state upon the skin it destroys the epidermis. Insects and fish thrown into it, immediately die. It has been employed with success in cases of caries, of cancers and of carcinomatous ulcers.—*Lond. and Edin. Phil. Mag.* iv. 391. *Edin. Med. and Surg. Jour.* xli. 248.

REFERENCES. *Crell's Annals. Aikin's Dict. art. Acetous Acid. For various processes for preparing this acid, see also Ure's Chem. Dict.* 4th *ed.* 7. *Thenard's Traité de Chim. and Chaptal. Despretz' method of making glacial acetic acid, by heating a mixture of one atom of acetate of lead, well dried, with one of concentrated sulphuric acid, Phil. Mag. and Ann.* vii. 317. *Parkes' Essay, on Pyroligneous Acid.*

The only correct mode of estimating the strength of acetic acid, is by its neutralizing power ; its specific gravity being no criterion.—*See a Table in Thomson's First Prin.* ii. 135.

Acetates.

The acetates are compounds formed by the union of acetic acid with bases. They are nearly all soluble in water, and can be decomposed by sulphuric, muriatic, nitric, hydrofluoric or phosphoric acids. When subjected to destructive distillation, they furnish in addition to the usual products, a modified vinegar, which has been termed *Pyroacetic Acid* or *Spirit.—See M. M. Macaire and Marcet's description and analysis of Pyroxilic and Pyroacetic Spirit, in Ann. of Phil.* xxiv. 69 ; *and contributions to the history of Pyroxylic Spirit and of its derived combinations, by Robert J. Kane, M. D., Lond. and Edin. Phil. Mag.* x. 45.

Acetate of Ammonia.—Atom. Num. 131—*Symb.* $(3H+N)+Ac$*
$+7$ aq.

Crystallizes with difficulty, being deliquesent and very soluble in water and in alcohol ; has a hot aromatic taste. It may be obtained in solution by saturating distilled vinegar with carbonate of ammonia, and it then constitutes the *Spirit of Mindererus,* long used in medicine as a febrifuge.

Acetate of Potassa.—Atom. Num. 116·15—*Symb.* $(O+Po.)+Ac+2$ aq.

Formerly known by the name of *Terra Foliata Tartari, Febrifuge Salt of Sylvius,* and *Diuretic Salt.* This salt, when cautiously evaporated, forms irregular crystals, which are with difficulty obtained, owing to their deliquesence. It exists, according to Vauquelin, in small quantity, in the sap of almost all plants, and is formed artificially by neutralizing carbonate of potassa with acetic acid, or by decomposing acetate of lime with sulphate of potassa.

Acetate of Soda.—Atom. Num. 136·3—*Symb.* $(O+So)+Ac+6$ aq.

Formerly known by the name of *Terra Foliata Crystallizata.* It crystallizes in long striated prisms ; has an acrid and bitter taste ; is soluble in a third of its weight of water, at 60° F. It is prepared by saturating acetic acid with carbonate of soda, and evaporating the solution. When it is employed in the manufacture of acetic acid, it is prepared by the decomposition of sulphate of soda by acetate of lime made with pyroligneous acid.

Acetate of Baryta is sometimes employed as a re-agent, and *Acetate of Alumina* is used by dyers and calico printers as a basis or mordaunt.

Acetates of Copper.

These salts have been carefully investigated by Berzelius and Phillips.—*Ann. of Phil.* xvii. 217. xviii. 21. xx. 161. xxiv. 192. xxviii. 188.

Acetate of Copper.—The neutral acetate may be formed either by

* *Ac* is used as an abbreviation for the acid of a salt when the symbol is complex. *Aq.* as heretofore, is an abbreviation for *aqua,* water.

dissolving oxide of copper or common verdigris in acetic acid or by decomposing sulphate of copper by acetate of lead. It crystallizes in oblique rhombic prisms, of a beautiful bluish-green colour, which are soluble in 20 times their weight of cold water, in 5 of boiling water, and in 14 of boiling alcohol. They consist of 1 atom acetic acid, 1 atom of the black oxide of copper and 1 of water=99.

Diacetate of Copper.—This constitutes the chief ingredient of the pigment called *Verdigris*, which is prepared in the large way by covering copper plates with cloth soaked in pyroligneous acid, or by covering copper plates with the refuse of the grape after the juice has been extracted for making wines, as is practiced in the south of France.— The saccharine matter contained in the husk furnishes acetic acid by fermentation, and in four or six weeks the plates acquire a coating of this salt. It consists of 1 atom acetic acid, 2 atoms black oxide of copper, and 6 atoms of water=144.

This salt is decomposed by water and converted into a soluble green *sesquiacetate* and an insoluble *tri-acetate.*—*See the papers above referred to and Thomson's First Prin.* ii. 383, *and Inorg. Chem.* ii. 672.

Acetate of Lead.—Atom. Num. 189·5—Symb. (O+Pb)+Ac+3 aq.

Known also by the names of *Saccharum Saturni* and *Sugar of Lead.*

This salt, when pure, crystallizes in long six-sided prismatic crystals ; it has a taste at first sweet, then astringent ; has no effect upon vegetable blues, being perfectly neutral ; is very soluble in water ; effloresces when exposed to the air, and is partially converted into a carbonate. It is prepared by dissolving either carbonate of lead or litharge in distilled vinegar. It is used in medicine as an external application, &c.; in the arts, in the preparation of acetate of alumine ; and in the laboratory as a re-agent.

Subacetate of Lead.—Atom. Num. 385·5—Symb. 3(O+Pb)+Ac.

This compound, commonly known by the name of *Extractum Saturni,* or *Goulard's Extract of Lead,* is prepared by boiling one part of neutral acetate, and two parts of litharge, deprived of carbonic acid by heat, with 25 parts of water. It crystallizes in white and opaque plates ; has a taste less sweet, and is less soluble in water, than the neutral acetate, and changes to green the syrup of violets. It has a strong attraction for vegetable colouring matter, and upon this principle was employed by Mr. Brande in his analysis of wines.—*Phil. Trans.* 1813.

This salt is called by Dr. Thomson the *Trisacetate,* and he has also described a *Diacetate,* formed by boiling with water a mixture of litharge and acetate of lead, in atomic proportions.—*First Prin.* ii. 373, and *Inorg. Chem.* ii. 642.

Oxalic Acid.—Atom. Num. 36—Symb. 3O+2C.

STATE AND PROPERTIES. Discovered by Scheele, and exists in the juice of several plants, especially in that of the *Rumex Acetosa, L.* or common sorrel, and in the *Oxalis Acetosella L.* or wood sorrel ; but

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it almost always occurs in combination either with lime or potassa.—
It may also be prepared artificially by the action of nitric acid upon
various vegetable and animal substances. It crystallizes in slender,
flattened four or six-sided prisms, with two-sided summits, the prima-
ry form of which is an oblique rhombic prism; it has a very acrid
taste, and reddens litmus strongly; is soluble in two parts of water at
60° and in its own weight at 212° and also in boiling alcohol; efflor-
esces when exposed to the air, and at a red heat is decomposed. It
differs, in composition, from all the other vegetable acids, in contain-
ing no hydrogen.—*Berzelius, Ann. de Chim. et de Phys.* xviii. 155.
Thomson's First Prin. ii. 100.   *See also Dobereiner, in Ann. de Chim.
et de Phys.* xix.

Oxalic acid may be easily made artificially, by digesting sugar in
five or six times its weight of nitric acid, and expelling the excess of
that acid by distillation, until a fluid of the consistence of syrup re-
mains in the retort. The residue, in cooling, yields crystals of oxalic
acid, the weight of which amounts to rather more than half the quan-
tity of the sugar employed. These crystals are to be re-dissolved in
water, and again crystallized, by which the pure acid is obtained.

Other processes have been proposed by Braconnot for obtaining this
acid from lichens.—*Ann. de Chim.* xxviii. 313.

ACTION ON THE ANIMAL ECONOMY. Oxalic acid is one of the most
powerful and rapidly fatal poisons that we possess; and frequent ac-
cidents have occurred in consequence of the resemblance of the crys-
tals to those of Epsom salts. Its acidity, however, will be a sufficient
mark of distinction, which can be detected either by the taste or by
its reddening blue papers. The solution also of a small quantity of
this acid, when added to chalk, causes effervescence, which is not the
case with the salt. When the acid has been swallowed, copious
draughts of lime-water, chalk or magnesia and water, should be ad-
ministered, and vomiting excited as speedily as possible. *Christison
and Coindet, in Edin. Med. and Surg. Jour.* 1823.

TESTS. Oxalic acid is distinguished from all other acids by the form
of its crystals, and by its forming, with lime-water, an insoluble pre-
cipitate. It is hence employed as a test for lime; but for this purpose
the combination of oxalic acid with ammonia is generally preferred.

Oxalates.—These compounds are either insoluble or sparingly solu-
ble in water, but they are all dissolved by the nitric, and also by mu-
riatic acid, except when the latter precipitates the bases of the salts.
The only oxalates remarkable for solubility are those of potassa, soda,
lithia, ammonia, alumina and iron.

These salts are decomposed at a red heat; but they are with diffi-
culty acted upon by the acids. They are formed either directly or by
double decomposition.

Oxalate of Ammonia.—*Atom. Num.* 71—*Symb.* (3H+N)+Ac+2 aq.

This salt crystallizes in long tetrahedrons, terminated by two-sided
summits; it has a very pungent taste; is soluble in two parts of wa-
ter, at 60° F. insoluble in alcohol. It is prepared by the direct union
of its constituents, and is employed in the laboratory as a test for
lime.

During the decomposition of this salt by heat, a sublimate of a pe-

culiar nature is formed, which is named by Dumas, its discoverer, *Oxalammide* or *Oxamide*, compounded of the words *oxalic* and *ammonia*. It is of a dirty white colour, insoluble in cold water, but is dissolved in boiling water, from which on cooling it is deposited, unchanged, in the form of whitish flocks of a confused crystalline appearance. When gently heated in an open tube it rises in vapour, and is again condensed on the cold part of the tube; but when sharply heated, it enters into fusion, and while part sublimes, another portion yields cyanogen gas, and leaves a very bulky carbonaceous residue. It consists, according to Dumas, of 2 atoms carbon, 1 atom nitrogen, 2 atoms hydrogen and 1 atom oxygen=36.—*Ann. de Chim. et de Phys.* xliv. 129.—*Berzelius, Traité de Chim.*

Binoxolate of Ammonia.—Atom. Num. 161—Symb. (3H+N)+2Ac +8 aq.

This salt may be formed by adding oxalic, sulphuric, nitric or muriatic acid to a solution of oxalate of ammonia and setting the solution aside (sufficiently concentrated) for crystallization.

Oxalate of Potassa.—Atom. Num. 92·15—Symb. (O+Po)+Ac+aq.

A neutral salt, which crystallizes with some difficulty in flat, oblique, four-sided prisms, terminated by diedral summits; it is soluble in about twice its weight of water, at 60° F.; has a cooling and bitter taste. It is prepared by neutralizing oxalic acid with carbonate of potassa.

Binoxalate of Potassa.—Atom. Num. 137·15—Symb. (O+Po)+2Ac +2 aq.

This salt crystallizes in rhombs, only slightly oblique; it has a sour, pungent bitterish taste, and reddens vegetable blues; is soluble in ten times its weight of boiling water. It exists ready formed, in the sorrel and other plants, from which it may be obtained by solution and crystallization. Artificially it may be obtained by adding oxalic acid to a concentrated solution of the natural oxalate. It is commonly known by the names of *Salt of Sorrel* or *Essential Salt of Lemons*, and is used for the removal of ink stains from linen, &c.

Quadroxalate of Potassa.—Atom. Num. 254·15—Symb. (O+Po)+4Ac +7 aq

A salt crystallizing in octahedrons, reddening litmus powerfully and less soluble in water than the preceding. It is obtained by digesting the binoxalate in nitric or muriatic acid.—*On these Oxalates consult Wollaston on Super-acid and Sub-acid Salts, in Phil. Trans. for 1808, and Berard, in Ann. de Chim.* lxxiii. 271. *An Oxalate and Binoxalate of Soda are also described by Dr. Thomson, First Prin.* ii.

Oxalate of Lime.—Atom. Num. 82·5—Symb. (O+Ca)+Ac+2 aq.

A white tasteless powder, insoluble in water, but soluble in nitric and muriatic acid; when heated to 560° F. it becomes anhydrous. It is a

frequent ingredient of urinary concretions, and is the basis of what is called the *Mulberry Calculus.* Artificially it is prepared by adding any soluble oxalate to a salt of lime.

Oxalate of Magnesia.—*Atom. Num.* 70·7—*Symb.* (O+Mg)+Ac+aq.

A white, tasteless powder, which is sparingly soluble in water. It is prepared by adding oxalate of ammonia to a hot concentrated solution of sulphate of magnesia. When the sulphate of magnesia is moderately diluted with cold water no precipitate is occasioned by the addition of the oxalate. On this fact is founded one of the best processes for separating lime from magnesia.

Tartaric Acid.—*Atom. Num.* 66—*Symb.* 5O+2H+4C.

STATE AND PROPERTIES. This acid was discovered by Scheele in 1770, and exists in combination with lime and potassa in the juice of several acidulous fruits. It occurs in prismatic crystals, the primary form of which is a right rhombic prism ; has a very sour taste, and reddens litmus powerfully ; is soluble in five or six times its weight of water at 60° F. ; when exposed to heat it melts, is decomposed, and yields, in addition to the usual products of destructive distillation, a distinct acid, to which the name of *Pyrotartaric Acid* is applied ; it undergoes no change by exposure to air, but its aqueous solution soon becomes covered with mould.

Tartaric acid is prepared by throwing into boiling water a mixture of 197·15 parts or one proportion of cream of tartar, with 50·5 parts or one proportion of chalk, decomposing the tartrate of lime which results, with one proportion of sulphuric acid, filtering and evaporating the solution.

This acid combines with bases and forms salts, called *Tartrates,* and it is distinguished by its forming a white precipitate, the bitartrate of potassa, when mixed with any salt of that alkali. Its great use is by the calico-printers, who thicken it with gum or roasted starch, and apply it to those parts of a piece of calico previously dyed red or blue as are to be rendered colourless by means of chloride of lime. The tartaric acid combining with the lime sets the chlorine at liberty, which immediately destroys the colour of the part of the cloth on which the thickened acid has been fixed.

Tartrate of Potassa.—*Atom. Num.* 131·15—*Symb.* (O+Po)+Ac +2 aq.

This salt, frequently called *Soluble Tartar,* occurs in crystals, the primary form of which is a right rhomboidal prism, and which are soluble in water, and attract moisture when exposed to the air. It is formed by neutralizing a solution of the bitartrate with carbonate of potassa.—*For an account of the forms of its crystals, see Brooke, in Ann. of Phil.* vii. 161.

Bitartrate of Potassa.—Atom. Num. 197·15*—Symb.* (O+Po)+2 Ac
+2 aq.

Also called *Super-tartrate of Potassa, Cream of Tartar,* and in an impure form, *Tartar.* This salt is very sparingly soluble in water, requiring sixty parts of cold and fourteen of boiling water for solution, from the latter of which it is deposited in small crystalline grains, the primary form of which is either a right rectangular, or a right rhombic prism ; it has a sour taste, and reddens vegetable blues. It exists in the juice of the grape, and owing to its insolubility, is deposited on the sides and bottom of wine casks ; from which source all the tartar of commerce is obtained, and which, by being purified, furnishes the cream of tartar of the shops. It is used in forming the *black* and *white flux,* and in the preparation of tartaric acid and the tartrates.—*For the crystalline form of this Salt, see Ann. of Phil.* x. 37, *and* xxiii. 161. *The processes commonly adopted in manufacturing this Salt, are described in Aikin's Chem. Dict.* ii. *art. Tartar.*

Tartrate of Potassa and Soda.—Atom. Num. 282·45.

This double salt, which has long been used in medicine under the name of *Rochelle Salt,* occurs in prismatic crystals, having often ten or twelve sides, the primary form of which is a right rhombic prism ; it is soluble in five parts of cold water, and in a less quantity of boiling water. It is obtained by neutralizing bitartrate of potassa with carbonate of soda.

Boro-tartrate of Potassa and Soda.—A salt made by dissolving one part of borax in eight parts of boiling water, and adding three parts of tartar, or as much as it is capable of dissolving. It has a place in most of the German Pharmacopœias under the name *Cremor Tartari Solubilis* and *Tartras Potassæ Boraxatus.* It is said to possess nearly the same properties as cream of tartar.—*Thomson's Inorg. Chem.* ii. 805.

Tartrate of Antimony and Potassa—Tartar Emetic.—Atom. Num. 350·35.

PROPERTIES. This salt commonly crystallizes in tetrahedrons, which are transparent when first formed, but become white and opake by exposure to the air. It has a styptic metallic taste ; reddens litmus slightly ; is soluble in fifteen parts of water at 60° F. and in three of boiling water ; its aqueous solution undergoes spontaneous decomposition by keeping.

PREPARATION. Tartar emetic is obtained by boiling protoxide of antimony with a solution of bitartrate of potassa. For this purpose, the oxide is variously prepared. The method recommended by Mr. Phillips is to boil 100 parts of metallic antimony in fine powder to dryness, in an iron vessel, with 200 parts of sulphuric acid ; and to boil the residual subsulphate with an equal weight of cream of tartar. The solution is then concentrated by evaporation, and allowed to cool in order that crystals may form. According to Dr. Thomson, this salt consists of two atoms tartaric acid, three protoxide of antimony, one atom of potassa and two atoms water,=354.—*First Prin.* ii. 441.

For a copious abstract of an elaborate memoir on Tartar Emetic, by M. Henry, of Paris, see the Supplement to Duncan's Edin. New Dispensatory, (1829.)

ACTION ON THE ANIMAL ECONOMY. Most commonly tartar emetic is evacuated by vomiting, before it can produce any striking constitutional effect. But in cases of poisoning when large doses have been exhibited, and it remains long on the stomach, burning pain in the stomach comes on, with purging, colic pains, violent and long continued vomiting; cramp is also common. The resemblance of these symptoms to cholera morbus will strike the physician.

TESTS. 1. Sulphuretted hydrogen gives an orange-red precipitate, —the *Sulphuret of Antimony.* 2. Carbonate of potash throws down a white precipitate. 3. The sulphuret obtained as above, after being dried, is placed in a small glass vessel, a stream of hydrogen is then passed on it from a proper apparatus,—heat is afterwards applied by a spirit lamp, and on producing an elevated temperature, metallic antimony is seen, either in minute globules, or in a spongy mass. This experiment, for which we are indebted to Professor Turner, depends on the property that hydrogen possesses of separating sulphur from antimony.— *See Dr. Turner, in Edin. Med. and Surg. Journal,* xxviii ; *Christison on Poisons ; and Beck's Medical Jurisprudence.*

Tartrate of Copper and Potassa.—This salt may be formed by boiling together oxide of copper and tartar and water. The solution yields by evaporation blue crystals, which have a sweetish taste, and contain a great proportion of metal. When tartar and copper, or its oxides, are boiled together, they dissolve, and by evaporating to dryness, a bluish-green powder is obtained, which, according to Leonardi, constitutes the better kind of pigment, called *Brunswick green.— Thomson's Inorg. Chem.* ii. 796.

Racemic or Paratartaric Acid.

Shown to be a distinct acid by John, in 1819, a view which was confirmed by Gay Lussac and Walckner in 1829.

PROPERTIES. This acid occurs in the form of prisms and of large oblique rhombs which are perfectly diaphanous ; is very sour, but without odour ; melts easily and becomes yellow when heated.

It possesses exactly the same composition and power of saturation as tartaric acid ;— in consequence of which Berzelius suggested the name of Paratartaric Acid.

PREPARATION. This acid may be prepared by saturating the tartar of sour wine with carbonate of soda, and crystallizing the double tartrate. The double paratartrate does not crystallize, and remains in the mother water. It is then decolourized as much as possible by animal charcoal and precipitated by a salt of lime or of lead—the precipitate, if a salt of lime, is decomposed by sulphuric acid—if of lead, by sulphuretted hydrogen. The solution then contains tartaric and paratartaric acid ; the last crystallizes first, and the tartaric acid only assumes the solid form when the mother water becomes of the consistence of syrup.—*Berzelius, Traité de Chim.* v. 83.

Berzelius describes several *Paratartrates.*

Citric Acid.—Atom. Num. 58*—Symb.* 4O+2H+4C.

STATE AND PROPERTIES. This acid, discovered by Scheele, is found in very large quantity in the juice of the lime and lemon. It crystallizes, in large and transparent rhomboidal prisms, which are terminated by four plane surfaces, and undergo no change in the air; when concentrated it has a very sour and almost insupportable taste, and reddens litmus powerfully; is soluble in an equal weight of cold, and half its weight of boiling water; when exposed to heat it is decomposed, and besides the usual products, a peculiar acid sublimes, called *Pyrocitric Acid.* It is obtained from lemon juice, by a process very similar to that for obtaining tartaric acid.

This acid is sometimes used as a substitute for lemon juice, and when added to the carbonates of potassa or soda, forms an effervescing draught. It combines with various bases, and forms *Citrates*, but these are of little importance.

- REFERENCES. *For a very full account of Citric Acid, see Parkes' Chem. Essays. Lassaigne, on Pyrocitric Acid, Ann. de Chim. et de Phys. or Repert. of Arts,* 2d ser. xlii. 251.

Malic Acid.—Atom. Num. 58*—Symb.* 4O+2H+4C. *Liebig.*

STATE AND PROPERTIES. This acid, discovered by Scheele in 1785, is found in most of the acidulous fruits, as grapes, currents, gooseberries, &c. and in the *Sempervivum tectorum, L.* and *Sorbus aucuparia, L.* and may be formed by digesting sugar with three times its weight of nitric acid. It is white, inodorous, and difficultly crystallizable; has a sour taste, resembling that of the citric and tartaric acids; is deliquescent and soluble in water and alcohol; has a specific gravity greater than that of water, and by the action of heat is converted into a distinct and volatile acid, called *Pyromalic Acid.*

The compounds of this acid with bases, called *Malates*, are mostly soluble in water.

REFERENCES. *Donovan, Le Grange, Vogel and Braconnot, on Malic Acid, in Ann. of Phil.* vi. 67; xii. 153; xiii. 51. *Braconnot and Labillardiere's proofs of the identity of the Sorbic and Malic Acid, Ann. de Chim. et de Phys.* viii. 149 *and* 214. *Thenard, Traité de Chim.*

Benzoic Acid.—Atom. Num. 113*—Symb.* 3O+5H+14C.

Flowers of Benzoin of the shops.

STATE AND PROPERTIES. Exists in the *Styrax Benzoin, Dryand.* And in the flowers of the *Melilotus officinalis, Lam.* It occurs in white opaque, prismatic crystals, of a satin appearance; has a sweetish and aromatic, rather than a sour taste, though it reddens litmus and unites with bases; is soluble in about 30 parts of boiling water, and very sparingly so in cold water; is also soluble in alcohol. It combines with bases and forms a class of salts, called *Benzoates*, most of which are soluble.

PREPARATION. This acid may be obtained by heating gum benzoin in an earthen pot, and receiving the acid as it sublimes in a cone of

paper placed over it ; or by boiling powdered gum benzoin in a large quantity of water, along with carbonate of potassa or lime, and adding muriatic acid to the solution after being filtered and evaporated. But perhaps the simplest process is to digest gum Benzoin in sulphuric acid, when a great quantity of beautifully crystallized and very pure benzoic acid is sublimed.

Benzule. One of the most interesting discoveries lately made in vegetable chemistry, is that of M. M. Wohler and Liebig, of the radical of benzoic acid. It is the first example of a radical consisting of three elements, and promises to throw much light on the nature of the vegetable principles in general.

The close connexion of benzoic acid and oil of bitter almonds, in which crystals of the acid are often deposited, as it was supposed from the oxidizement of the oil, led the above named chemists to analyze it, when they found it to consist of $2O+6H+14C$; that is, it contains one atom of hydrogen more, and one of hydrogen less, than benzoic acid. They consider both, therefore, to be compounds of the same radical composed of $2O+5H+14C$, which they propose to call *Benzule*, from the Greek *ule, matter* or *base*. If this radical be represented by Bz, then $Bz+O=$benzoic acid and $Bz+H=$oil of bitter almonds.

If the oil be exposed to a current of chlorine, there are formed two products, $Cl+Bz$ and $Cl+H$, chloride of benzule and muriatic acid. With hydrated bases, it gives a benzoate of the oxide and a chloride of the metal. Distilled with cyanide of mercury, it gives a cyanide of benzule and a chloride of mercury. With sulphuret of lead, and iodide and bromide of potassium, it gives, in the same way, a sulphuret and iodide and a bromide of benzule, while the chlorine unites with the metal. The iodide and bromide are crystallizable and volatile, and all three are decomposed by water and bases like the chloride.—*Johnston's Report on Chemistry.*

REFERENCES. *Vogel, on Benzoic Acid in Melilotus Officinalis, &c. Ann. of Phil.* xvi. 227. *Other sources of, Brande's Jour.* xviii. 319. *Hisinger, on the Benzoates, Phil. Mag.* xl. *Trommsdorf and Berzelius, on the same, Ann. de Chim.* xi. *and* xc. *Faraday, in Brande's Jour.* vi. 159.

Gallic Acid.—Atom. Num. 85—*Symb.* $5O+3H+7C$.

Discovered by Scheele in 1786.

STATE AND PROPERTIES. It exists ready formed in the bark of many trees and in gall-nuts.—When pure it is in the form of whitish crystals; has a sour taste and reddens litmus ; is soluble in twenty parts of water at 60°, and in three parts at 212°, and is also soluble in alcohol and ether; when heated in the air it exhales a peculiar smell, and at a high heat takes fire.

With lime-water, gallic acid yields a brownish-green precipitate, which is redissolved by an excess of the solution, and acquires a reddish tint. It is distinguished from tannin by causing no precipitate in a solution of gelatine. With a salt of iron, it forms a dark blue-coloured compound, which is the basis of ink. The finest colour is procured when the peroxide and protoxide of iron are mixed together. This character distinguishes gallic acid from every other substance excepting tannin.

When the impure acid obtained from the gall-nut by sublimation is

exposed to a temperature of 350° F. the mass enters into fusion and a volatile matter passes over and condenses on cool surfaces in the form of delicate long scaly crystals. These constitute the *Pyrogallic* acid of Braconnot.

PREPARATION. Pure gallic acid may be obtained, according to Dobereiner, in a few minutes by the following process : A concentrated decoction of gall-nuts, mixed with a little acetic acid to decompose the gallate of lime, is shaken for one minute with a quantity of ether.— The gallic acid is taken up by the ether, and by spontaneous evaporation on a watch glass is obtained in small colourless prisms. If longer digested, the liquid separates into three portions. The lightest contains the gallic and acetic acids, if the latter be present in excess ; the next, an ethereal solution of tannin ; and the heaviest, the water and extractive matter.

The salts of gallic acid, called *Gallates*, have been imperfectly examined. The gallates of potassa, soda, and ammonia, are soluble in water ; but most of the other gallates are of sparing solubility. On this account many of the metallic solutions are precipitated by gallic acid.

REFERENCES. *B. La Grange's facts towards a history of Gallic Acid, containing a notice of various processes for obtaining it, and of some of the Gallates, Ann. de Chim. or Repert. of Arts.* 2d ser. ii. 227, 283. *Thenard, Traité de Chim. Berzelius, Ann. of Phil.* v. 179.

Ellagic Acid.—Exists, according to Braconnot, along with the gallic acid, in infusion of galls, but its characters have been but imperfectly examined. Its name is derived from the word *galle,* reversed.—*See Vauquelin, Ann. de Chim. et de Phys.* xxxvii. 175. *Thenard, Traité de Chim.*

The remaining vegetable acids are arranged alphabetically.

Aspartic Acid.—Discovered and its properties investigated by M. M. Henry and Plisson, in 1829. A white powder consisting of minute crystals, having a slightly acid taste, and reddening the infusion of litmus. Obtained by mixing acetate of lead with the juice of the shoots of asparagus, washing the insoluble salt which is produced, mixing it with water, decomposing by a current of sulphuretted hydrogen gas, and evaporating the solution.— *Thomson's Inorg. Chem.* ii. 160.

Boletic Acid.—Discovered by Braconnot in the *Boletus Pseudo-igniarius.* It is in the form of prismatic crystals ; reddens litmus, and unites with some bases.— *Braconnot on Boletic Acid and the Boletates, Ann. of Phil.* ii. 469.

Camphoric Acid.—Obtained from camphor by repeated distillations with nitric acid. It assumes the form of plumose crystals, has a sour and somewhat bitter taste, and an aromatic odour ; reddens litmus ; is very sparingly soluble in cold water—more so in hot ; is very soluble in hot alcohol ; when thrown upon coals is completely exhaled in the form of a thick, white and aromatic fumes.— *For Liebig's Experiments on the composition of this acid, see Jour. of the Roy. Inst.* ii. 630. *Bucholz on Camphoric Acid and the Camphorates, Ann. of Phil.* ii. 313.

Carbazotic Acid.—Obtained by the action of nitric acid upon indigo or silk. When pure this acid is in the form of brilliant crystalline plates, of a yellow colour ; is soluble readily in alcohol and ether, but

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sparingly soluble in cold water ; is fused and volatilized by heat, without decomposition, but when suddenly exposed to strong heat, inflames without explosion, and burns with a yellow flame ; reddens litmus paper, and is extremely bitter.—*Brande's Jour. N. S.* ii. 210, *and* iii. 490, *where several compounds of this acid, with bases, are also described.*

Chloroxalic Acid.—When crystallizable acetic acid is put into a glass vessel full of dry chlorine, and exposed for a day to bright sunshine, muriatic acid gas is generated, and during the night chloroxalic acid is deposited in dendritic crystals or small rhombic scales. In order to obtain it pure, the chlorine should be in excess, and the gases subsequently expelled from the flask by dry air. The new acid is very volatile and deliquescent, and when evaporated in *vacuo* yields rhombic crystals.—*Dumas.*

Caincic Acid.—Discovered by Pelletier and Caventou in the caincá root *Chiococca racemosa,* to which the medical properties of the root are supposed to be owing. It may be prepared by acidulating by muriatic acid a very concentrated decoction of the root ; and allowing the liquor to repose for several days, when the acid gradually crystallizes. —*Berzelius, Traité de Chim.* v. 99.

Crameric Acid, is obtained according to M. Peschier, from the astringent root of the *Crameria triandra.—Ann. de Chim.*

Croconic Acid.—The gray flaky substance which deposits in cool vessels during the preparation of potassium from cream of tartar, when treated with water, becomes red, and on exposure to the air a reddish yellow solution is formed, which by gentle evaporation yields croconate of potassa in crystals of the same colour as the solution : the residual liquid contains bicarbonate and oxalate of potassa. In order to separate croconic acid, these crystals, purified by a second crystallization and reduced to fine powder, are put into absolute alcohol to which sulphuric acid of the specific gravity 1·78, in quantity insufficient for combining with all the alkali of the croconate, is added. The mixture is gently warmed during several hours, and frequently shaken, until a drop of the solution, mixed with muriate of baryta, causes no turbidity. The yellow alcoholic solution of croconic acid is then separated from sulphate of potassa by filtration, and the acid obtained by expelling the alcohol. By solution in water and spontaneous evaporation, croconic acid yields transparent prismatic crystals of a yellow colour, which are inodorous, have an astringent taste, redden litmus, and neutralize alkaline bases ; the acid as well as its salts are decomposed at a high temperature, giving a deposit of charcoal. According to the analysis of Gmelin, the discoverer, this acid consists of 5 atoms carbon+4 atoms oxygen.—*Gmelin's Handbuch.* —*Turner's Chem.*

Igasuric Acid.—Discovered by Pelletier and Caventou, in combination with strychnine, in the *Strychnos Ignatii,* and *Strychnos Nux Vomica,* though its existence, as different from all other acids, is doubtful. It closely resembles the meconic acid, but does not, like that, produce a red colour when added to salts of iron ; crystallizes in small hard crystals ; has an acid and very styptic taste ; is soluble in water and in alcohol.—*Ann. de Chim. et de Phys.* x. 142. *Ure's Chem. Dict.* 56.

Indigotic Acid.—First described by Chevreul, and is obtained by the

action of nitric acid upon indigo. It appears to be distinct from the carbazotic acid formed by a similar process.

Kinic Acid, is found in the bark of the Cinchona; it is difficultly crystallizable; has a very acid taste, but when pure wholly destitute of bitterness; reddens litmus permanently; is very soluble in water; is not altered by exposure to air, and forms no precipitates with the salts of mercury, lead or silver.— *Vauquelin, in Ann. de Chim.* lix. 162. *Henry,* ii. 256.

Laccic Acid.—Obtained from the *White Lac* of Madras, by Dr. John. It occurs in crystals of a wine-yellow colour; has a very sour taste; is soluble in water, alcohol and ether; forms white precipitates in solutions of lead and mercury, but has no effect upon lime-water, nor the nitrates of silver and baryta. It should in strictness be classed among the animal acids.—*A full account of the properties of this acid and of the substance that affords it, may be found in Dr. Pearson's paper, in the Phil. Trans.* 1794.

Lactucic Acid.—Discovered by Pfaff in the juice of the *Lactuca Virosa.* It is obtained by precipitating the clarified juice by sulphate of copper or acetate of lead, washing the precipitate and decomposing it by sulphuretted hydrogen. By the evaporation of the liquor the lactucic acid is deposited in colourless crystals. It closely resembles oxalic acid, but differs, in producing an abundant green precipitate in solutions of the neutral salts of iron,—and a brown precipitate with the solution of sulphate of copper.—*Berzelius, Traité de Chim.* v. 97.

Meconic Acid.—This acid is found in opium, combined with morphine. It occurs in crystals of various forms, which fuse at 212° F., and sublime without decomposition; reddens litmus; is very sour; is soluble in water and alcohol; produces an intense red colour with solutions of the peroxide of iron, without causing any precipitation.— *For a good account of Meconic Acid, and the Meconates, See Ure's Chem. Dict. 4th ed. Dr. Hares process for obtaining the acid will be found in Sill. Jour.* xii. 293.

Mellitic Acid.—Found in a rare substance called *Honey-stone,* occasionally met with in Thuringia, in Germany. It crystallizes in hard prisms, or in fine needles, forming sometimes by their re-union, a globular mass; has a taste first sour and then bitter; is not very soluble in water; when placed upon a hot metallic plate it gives off gray fumes which are without odour.—*Ure's Chem. Dict.*

Moric or Moroxylic Acid.—Discovered by Klaproth, and combined with lime, exists in the bark of the *Morus Alba, L.,* or white mulberry. It crystallizes in fine needles; has the taste of succinic acid; reddens litmus; is not altered by exposure; is soluble in water and alcohol; and when heated in a retort is partly decomposed.—*Klaproth, in Nicholson's Jour.* vii. 129. *Henry,* ii. 253.

Mucic or Saccholactic Acid.—Discovered by Scheele in 1780, and obtained by the action of nitric acid upon gum, manna and the sugar of milk. When pure this acid occurs in the form of white crystals; has a slightly acid taste, and reddens litmus feebly; is soluble in sixty times its weight of boiling water, and insoluble in alcohol; when heated it is decomposed, and yields a volatile white substance, which has been called *Pyro-mucic Acid.*— *On this acid and the Mucates, see Thenard, Traité de Chim.*

Pectic Acid.—This acid is found in all vegetables; it occurs in the form of a colourless jelly; has no odour, and a slightly acid taste; is nearly insoluble in hot water as well as cold; possesses the remarkable property of gelatinizing large masses of sugar. It was discovered by Braconnot, though it is still somewhat doubtful whether it is a distinct acid.—*Braconnot, in Ann. de Chim. et de Phys.* xxviii. 173. xxx. 96. *Thenard, Traité de Chim. Dr. Torrey on the Pectic Acid, and its identity with Sclerotin, N. Y. Med. and Phys. Jour.* vi. 481.

The *Phosphoric* and *Hydrocyanic Acids* are also found in vegetables. The former in all the varieties of grain, in combination chiefly with potassa and lime. The latter may be distilled from bitter almonds, from the leaves of the laurel, &c.—*Saussure, in Nicholson's Jour.* xxv. 279. *Vauquelin, Ann. de Chim.* xlv. 206.

Rocellic Acid.—Discovered by Heeren in the *Rocella tinctoria,* and obtained by acting on the lichen with a solution of ammonia, precipitating with chloride of calcium and decomposing the rocellate of lime by hydrochloric acid.

Suberic Acid.—Formed by digesting cork in nitric acid. When pure it is a white powder; has a feeble taste, and has little action on litmus; is sparingly soluble in cold water, very much so in boiling water; exposed to gentle heat it melts like fatty matter.—*Thenard, Traité de Chim.*

Succinic Acid.—Obtained by distillation from amber. When perfectly pure it is white, transparent, and crystallizes in prisms; has a sour and somewhat acrid taste, and reddens litmus; is not altered by exposure; is sparingly soluble in water; when exposed to heat it fuses, undergoes decomposition, and in part sublimes, emitting a very peculiar and characteristic odour.

The compounds of this acid with bases, called *Succinates,* have been but little examined. The *Succinate of Ammonia,* easily formed by the direct union of its elements, is employed for separating iron from manganese, the succinate of the peroxide of iron being quite insoluble in water, provided the solutions are neutral. The succinate of manganese, on the contrary is soluble.—*Berzelius, Ann. of Phil.* ix. 108.— *John, same work.* xv. 388.

Ulmic Acid.—The substance formerly called *Ulmin,* and shown to be a distinct acid by Boullay in 1830. It exists ready formed in bark, and makes its appearance in a variety of vegetable decompositions. It constitutes the essential ingredient of *peat* and of *umber,* and what is usually called vegetable manure.—*Ann. de Chim. et de Phys.* xliii. 273.

Valerianic Acid.—Discovered by Grote in the root of the *Valeriana officinalis.* It is colourless, oleaginous—has an acid, piquant odour. It combines with bases and forms *Valerianates,* which are distinguished by a peculiar sweetish taste.

Zumic Acid.—Discovered by Braconnot in several vegetable substances which have undergone the acetous fermentation. It appears from the observations of Vogel to be the lactic acid.—*Ann. of Phil.* xii.

SECTION II.

VEGETABLE SALIFIABLE BASES OR ALKALIES.

Under this head are classed all those proximate vegetable principles capable of uniting with acids, and of forming with them saline compounds.

The existence of this class of bodies was discovered by Sertuerner, in 1805, but they excited no attention until about 1816. Since that time this department has been cultivated with much success by several chemists, but especially by M. Robiquet, and M. M. Pelletier and Caventou.

The vegetable alkalies, according to the researches of Pelletier and Dumas, consist of carbon, hydrogen, oxygen and nitrogen. [*Ann. de Chim. et de Phys.* xxiv.] They are all solid, white, bitter or acrid, without odour, heavier than water, and mostly crystalline; they change vegetable blues to green ; are insoluble, or nearly so, in cold water, but soluble in alcohol, especially if hot ; most of them are poisonous, and many are valuable in medicine.

These substances are never found in a free state in plants, but appear in every case to be combined with an acid, forming a salt, more or less soluble in water. And the process for separating them which is generally applicable, is to digest or macerate the substance containing the alkali, in a large quantity of water, and to add to the solution a more powerful salifiable base, as potassa, soda or ammonia, or to boil it for a few minutes with pure lime or magnesia. The vegetable alkali being thus separated from its union with the acid, and being insoluble in water, is precipitated. This precipitate, mixed with some animal charcoal, is then dissolved in hot alcohol, and the solution filtered while hot and evaporated ; and the pure alkali is thus obtained.

According to Serullas, the vegetable alkalies may be precipitated by iodic acid, which he considers a very delicate test of their presence in solutions.—*Ann. de Chim.* xlv. *or Jour. of the Roy. Inst.* ii. 615.

Different opinions are still entertained concerning the nature of the vegetable alkalies. They may be reduced to the following :

1. That they combine with acids in the same manner as metallic oxides, and give birth to anhydrous salts composed of the two bodies in contact. This is the most generally received.

2. That they contain a certain quantity of ammonia to which they owe their powers as bases, and with which some organic matter is combined in the same way as many vegetable substances are united with sulphuric acid ; and that this substance enters with the ammonia into the salt formed.

3. That the vegetable alkalies like ammonia have the power of acting as bases only when combined with water ; in which case the proportions in which they saturate the acids depend upon the quantity of water. Or in other words, the vegetable alkalies considered in this point of view, only combine with the hydrous acids, and without setting at liberty the water contained in these acids.—*Berzelius, Traité de Chim.* v. 123.

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Morphine.

This is the active principle of opium, (*Papaver Somniferum*, *L.*) in which it is combined with various other principles. It occurs in crystals of a brilliant lustre, which are mostly irregular six-sided prisms, with diedral summits, but the primary form of which, according to Brooke, is a right rhombic prism; it is insoluble in cold, and sparingly soluble in boiling water; soluble in alcohol, and in solution intensely bitter; has an alkaline reaction, and forms salts with acids, which are mostly capable of crystallizing.

PREPARATION. Various processes have been proposed for separating this alkali. That of Robiquet, which is probably the best, is to boil the concentrated infusion of a pound of opium for a quarter of an hour with about 150 grains of pure magnesia. A grayish crystalline precipitate results, which consists of meconate of magnesia, morphine, narcotine, colouring matter and the excess of magnesia. This powder is collected on a filter, edulcorated with cold water, and then digested at a temperature of 120° or 130° F. in dilute alcohol, which removes the narcotine, and the greater part of the colouring matter. The morphine is then taken up by concentrated boiling alcohol, and is deposited in crystals on cooling.

A convenient process, suggested by Dr. Thomson, is to precipitate the morphine by ammonia, and to purify it by solution in acetic acid, and digestion in animal charcoal, deprived of phosphate of lime by muriatic acid.—*Ann. of Phil.* xv. 471.

ACTION ON THE ANIMAL ECONOMY. It appears that notwithstanding the insolubility of morphine, it is the narcotic principle of opium. Direct experiments have sufficiently proved this. If for example, we make a solution of this substance in oil, we perceive violent narcotic effects, even in a small dose, such as a quarter or half a grain, but these are still more marked when the morphine is combined with acids, probably because its salts are more soluble than it is itself in an uncombined state.

Salts of Morphine.

These salts may be readily obtained by dissolving pure morphine in dilute acid and evaporating the solution. They have long been used for medicinal purposes, and are found to possess all the good qualities of opium, without its inconveniences.

Muriate of Morphine.—Usually crystallizes in tufts of acicular crystals, which are neutral and anhydrous. It is obtained by the direct action of muriatic acid gas upon morphine, or by dissolving the alkali in dilute muriatic acid. The process employed by Dr. A. T. Thomson is to decompose the aqueous solution of opium by muriate of baryta, of which a quantity is used exactly sufficient for precipitating the meconic acid. The muriates of morphine and narcotine are then separated by crystallization. This salt has recently come into use in medical practice in consequence of its being more uniform in its constitution, than the other salts.—[For a detailed account of the mode of preparing this salt, see *Edin. Med. and Surg. Jour. Nos.* 107 and 111.]

Sulphate of Morphine, crystallizes in silky tufts, much resembling sulphate of quinine, from which it may be distinguished by its becom-

ing red when heated with concentrated nitric acid. It may be obtained by the direct union of sulphuric acid with morphine.

Acetate of Morphine.—Obtained by dissolving morphine in acetic acid. In order to obtain it in the solid state, it must be evaporated to dryness, and in this process some of the acid is usually expelled. It is therefore necessary that it should be preserved in the form of solution, and care should be used that the acid is in excess.

The compound called *Black Drop*, consists of opium combined with some vegetable acid, generally in an impure state. Those most commonly used are the citric and acetic, combined with aromatics and sweet substances.

REFERENCES. *For detecting Acetate of Morphine when given for criminal purposes, a process has been described by M. Lassaigne, for which see Ann de Chim. et de Phys.* xxv. 102, *or Turner's Chem.* 768. *See also Hare's Compend,* 266 *For the medicinal preparations of Morphine and its Salts, see Magendie's Formulary, Carpenter on the Salts of Morphine, Chapman's Jour.* v. 248.

Narcotine.—This substance, though not regarded as a vegetable alkali,* may be conveniently noticed in connection with morphine. It dissolves in ether and alcohol, the latter, though diluted, acting as a solvent for it by the aid of heat; and it crystallizes from its solutions in the form of fine needles or rhomboidal prisms; it exerts no action on vegetable colours; is without taste or smell.

Narcotine is easily prepared by evaporating an aqueous infusion of opium to the consistence of an extract, and digesting it in sulphuric ether. From this solvent it may be obtained by evaporation, in the form of crystals. In the same manner morphine may be purified from narcotine. But an easier process is founded upon the property discovered by Duflos, that carbonate of potassa precipitates narcotine, but not morphine.

The unpleasant stimulating properties of opium are attributed by Magendie to the presence of narcotine, the ill effects of which, according to the experiments of the same physiologist, are in a great degree counteracted by acetic acid. These results, though they require confirmation, render it probable that the superiority assigned to the *Black Drop* over the common tincture of opium of the Pharmacopœia, is owing to the vegetable acids which enter into its composition.

Some physicians, however, discard the medical distinctions generally drawn between morphine and narcotine, and assert that denarcotized opium or laudanum, in its effect, differs in no respect from common laudanum, except in being considerably weaker.—*See the views of Prof. Tully and others, in Silliman's Chem.* ii. 491.

Codeine and Narceine.

Besides morphine and narcotine, two other alkalies have been found in opium, the one called *Codeine,* discovered by Robiquet in 1832; the other named *Narceine,* discovered by Pelletier during the same year.

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* Berzelius, however, thinks narcotine should be ranked among the vegetable alkalies, because it possesses the property of combining with acids and forming salts, some of which are crystalline.—*Traité de Chim.* v. 137.

Cinchonine.

Discovered by Dr. Duncan, jun. in 1803, though its alkaline nature was first settled by Pelletier and Caventou, in 1820. It exists in the *Cinchona condaminea*, or pale bark, combined with kinic acid. It is white and crystalline, requires 2,500 times its weight of boiling water for solution, and is insoluble in cold water; is soluble in boiling alcohol, and in small quantity in oil and ether; has a bitter taste, though scarcely sensible unless in solution; it unites with all the acids, and forms salts. It is obtained by a process similar to that described for obtaining morphine.—*Edin. New Dispensary*, 11th ed. 299.

Both the *Sulphate* and *Acetate of Cinchonine* are employed in medicine; the first of these salts is very soluble in water, the second much less so; but an excess of acid dissolves it readily.—For a description of several salts of cinchonine, see *Berzelius, Traité de Chim.* v. 164.

Quinine.

Discovered by Pelletier and Caventou. Exists, combined with kinic acid, in the *Cinchona cordifolia*, or yellow bark, and together with cinchonine in the *Cinchona oblongifolia*, or red bark. It is usually in the form of a white porous mass, but Pelletier has succeeded in crystallizing it in the form of silky flexible tufts, by leaving a pure alcoholic solution undisturbed. [*Magendie's Formulary.*] It is soluble in alcohol, forming a solution which is intensely bitter, and possessing distinct alkaline reaction; is also soluble in ether, but almost insoluble in water; is distinguished from cinchonine by its habitudes with acids, and by the different properties which characterize its salts.

Sulphate of Quinine.—Though quinine combines with most of the acids, the form in which it is commonly exhibited is that of the Sulphate. This salt, which consists of 90 parts of the alkali and 10 of the acid, crystallizes in delicate white needles, having the appearance of amianthus. It is less soluble in water than the sulphate of cinchonine, but is very bitter. It dissolves readily in strong alcohol by the aid of heat, a character which affords a useful test of its purity. One grain of the sulphate of quinine, when pure, will render nearly a pound and a half of water sensible bitter.—*See R. Phillips on the means of ascertaining the purity of Sulphate of Quinine, Phil. Mag. and Ann.* iii. 111.

The presence of cinchonine in the sulphate of quinine may be detected by the following method. A grain of the salt in fine powder is shaken with a dram of ether, and a dram of ammonia is added and the whole well shaken. If no cinchonine be present, the line of separation of the two fluids is clean; if the smallest quantity be present, it is deposited in this line.—*Kindt, in Brande's Archiv.—Johnston's Report.*

✝ Strychnine.

Discovered in 1818, by Pelletier and Caventou, in the fruit of the *Strychnos ignatia* and *Strychnos nux vomica*, in which it is combined with igasuric acid; it has since been extracted by the same chemists from the famous Upas of Java. It occurs in the form of small four-

✝ warme milk is a good antidote

sided prisms; it is intolerable bitter, and leaves an impression on the organs of taste like that of some of the metallic salts; has no smell, and is not changed by exposure to air; it is nearly insoluble in water, requiring more than 6000 times its weight of cold, and 2500 of boiling water for solution; has a distinct alkaline reaction and forms salts with acids, most of which are soluble in water.—*Pelletier and Caventou, in Ann. de Chim. et de Phys.* x. *and* xxvi. *Henry, in Jour. de Phar.* viii. 401.

Strychnine is one of the most virulent poisons hitherto discovered, and is the poisonous principle of the substance in which it is contained. Its energy is so great, that half a grain blown into the throat of a rabbit occasioned death in the course of five minutes. Its operation is always accompanied with symptoms of locked jaw and other tetanic affections.—*See Magendie and Christison on Poisons,* 637.

The salts of strychnine, in consequence of their greater solubility, are more active, and consequently more intensely poisonous than their base. They are, nevertheless, employed medicinally in small doses with decided advantage.

Brucine.

Discovered by Pelletier and Caventou, in the *Brucea antidysenterica,* and, in small quantities, also in the *Strychnos nux vomica.* It crystallizes in oblique prisms, the bases of which are parallelograms: in taste and poisonous qualities, it is very similar to strychnine, but is twelve or sixteen times less energetic than that alkali; it is soluble both in hot and cold alcohol, especially in the former; and it crystallizes when its solution is evaporated; is soluble also in dilute alcohol, by aid of heat, and on this property is formed the method for separating it from strychnine; it is more soluble in water than most of the other vegetable alkalies, requiring only 850 times its weight of cold, and 500 of boiling water for solution.

Emetine.

Discovered in 1817, by Pelletier, and is found in the *Cephaelis Ipecacuanha, Willd,* and *Viola Ipecacuanha.* When pure it is white and pulverulent, and not deliquescent; has a bitter and disagreeable taste; is sparingly soluble in cold, but more freely in hot water; is insoluble in ether, but readily soluble in alcohol; has a distinct alkaline reaction, and neutralizes acids, but its salts are little disposed to crystallize; its effects appear to be neutralized by decoction of galls.—*Magendie's Formulary,* 40.

It is to this principle that ipecacuanha owes its emetic properties.

Veratrine.

This alkali, discovered by Pelletier and Caventou, in 1819, exists combined with gallic acid, in the seeds of the *Veratrum sabadilla, Retz,* and the roots of *Veratrum album, L.* or white hellebore; and *Colchicum autumnale, L.* or meadow saffron. It is white, pulverulent, inodorous, and of an acrid taste; requires 1000 times its weight of boiling, and still more of cold water for solution; is very soluble in alcohol, and may also be dissolved, though less readily, by means of ether; has an alkaline reaction, and neutralizes acids, but it is a weaker

base than morphine, quinine or strychnine; it acts with singular energy on the membrane of the nose, exciting violent sneezings though in very minute quantity; when taken internally in very small doses, it produces excessive irritation of the mucous coat of the stomach and intestines, and a few grains were found to be fatal to the lower animals.—*Jour. de Phar.* vi. *Magendie's Formulary*, 61.

Sanguinarine.

Discovered by the late professor Dana, of New-York, in the root of the *Sanguinaria canadensis*, L. or blood root. It usually occurs in the form of a soft, white powder; but by the spontaneous evaporation of an alcoholic solution may be obtained in masses which exhibit a crystalline structure; has no odour, but a taste bitter and afterwards acrid; changes the blue of litmus to green, the yellow of tumeric to brown; combines with acids and forms neutral salts of a *red colour.*—*See Dana, in N. Y. Med. and Phys. Jour.* vi. 218, *and Dr. Tully and Mr. A. A. Hayes, in Silliman's Chem.* ii. 503.

According to Dr. Tully the medicinal virtues of blood root reside in this principle, and are not impaired by combination with acids. It is medicinally deobstruent, acrid, narcotic and emetic.—*See Professor Tully's Prize Dissertation on Sanguinaria, in the American Med. Recorder*, xiii.

The remaining vegetable alkalies are arranged alphabetically.

Atropine.—Discovered by Brandes, in the *Atropa belladonna*, L. or deadly nightshade. When pure it is snow-white, when impure yellowish; it has no taste; is almost insoluble in cold water, except when recently precipitated; it neutralizes acids and forms salts, the watery solutions of which give out by evaporation, vapours which dilate the pupil of the eye and produce violent headache, nausea and giddiness. —*See Ure's Chem. Dict. 4th ed.* 181.

Buxine.—Announced by Fouré as an alkali existing in the box, *Buxus sempervirens.* It has a bitter taste; is insoluble in water, but soluble in alcohol and in small quantity in ether.—*Berzelius*, v. 191.

Corydaline.—Discovered by M. Wackenroder, in the root of the *Fumaria cava, Mil.* and *Corydalis tuberosa, De Cande.* It is obtained from its alcoholic solution in the form of colourless prismatic crystals; it acts as an alkali upon vegetable colours, and combines with acids, forming extremely bitter salts; its nitric solution becomes, when heated and concentrated, of a blood-red colour.—*Phil. Mag. and Ann.* iv. 151.

Cro'onine.—Exists according to Brandes in the seed of the *Croton tiglium.*—*Berzelius*, v. 190.

Curarine.—A basis discovered by Boussingault and Roulin, in a matter which the natives of South America employ in poisoning their arrows, and which they call *curara* or *urari.* Prepared according to the process of Pelletier and Petroz, it is an uncrystallizable yellowish mass, which has a very bitter taste, and deliquesces upon exposure to the air. It forms neutral salts with the acids. Its poisonous effects are more decided than those of the curara from which it is obtained.— *Berzelius*, v. 181.

Cynapine.—Discovered by Professor Ficinus of Dresden, in the

Aethusa Cynapium, or lesser hemlock. It is crystallizable, and soluble in water and alcohol, but not in ether. The crystals are in the form of a rhombic prism, which is also that of the crystals of the sulphate. — *Turner*.

Daphnine.—A basis discovered by Vauquelin in the *Daphne Meze-rion*.

Daturine.—Obtained by M. Brandes, from the *Datura stramonium, L*. It is similar to atropine, and perhaps identical with it.

Delphine or *Delphinine*.—Discovered by MM. Feneulle and Las-saigne in the *Delphinium staphysagria, L*. or *Stavesacre*. It is in the form of a white powder, crystallizing when moist, but becoming opaque by exposure to dry air; it has no smell, but a taste at first bitter and afterwards becoming acrid; is sparingly soluble in water, but freely so in alcohol and ether; it combines with many acids and forms neutral salts, whose taste is extremely bitter and acrid; it is precipitated by alkalies in the form of a white jelly.—*Ann. de Chim. et de Phys.* xii. *Magendie*.

Digitaline.—Extracted, by M. Le Royer, from the leaves of the *Di-gitalis purpurea, L*. or foxglove. It is a brown, pasty substance, slowly restoring the blue colour of reddened litmus; very bitter and very deliquescent; it is difficultly crystallizable; but seems capable of crystallizing from its alcoholic solution; it combines with acids, and has great activity on the animal system.—*Brande's Jour.* xviii. 178.

Essenbeckine.—A supposed basis discovered by Buchner, in *Essenbeckia febrifuga*. It has a bitter taste like quinine.—*Berzelius*, v. 190.

Eupatorine.—A basis discovered by Riphini in the *Eupatorium can-nabinum*.—*Berzelius*, v. 192.

Hyoscyamine.—Extracted by Brandes, from the *Hyoscyamus niger, L*. or black henbane; it crystallizes in long prisms, is not easily altered in a high temperature, even when heated to redness with charcoal; when saturated with sulphuric or nitric acid forms very characteristic salts. —*Ann. of Phil.* xvi. 69.

Nicotine.—The active principle of tobacco, *Nicotiana tabacum*. It is a volatile alkali. Its solution is colourless; has the peculiar smell of tobacco, and occasions violent sneezing; has an acrid taste, and possesses poisonous qualities.—(*Vauquelin, in Ann. de Chim.* lxxi. 139.) Berzelius describes several salts of nicotine.

Solanine.—Discovered by Desfosses, and exists combined with malic acid in the berries of the *Solanum nigrum, L*. and in the leaves of the *Solanum dulcamara, L*. When pure it occurs in the form of a white, opaque, and sometimes pearly powder; it has no smell, but a slightly bitter and nauseous taste; is insoluble in cold water, very sparingly soluble in hot, and slightly so in alcohol; acts faintly on turmeric, but unites with acids and forms neutral salts, which, however, are mostly uncrystallizable.—*Jour. de Phar.* vii. and viii. *Magendie's Form.* 79.

According to Magendie this alkali, like opium, may produce vomiting and sleep, but its emetic powers seem to be more decided, while its narcotic properties are less so than those of opium.

Violine.—A vegetable alkali, thought to exist in the *Viola odorata*.

It has properties analogous to emetine and may be extracted from the root, leaves, flowers and seeds of the plant.—*Jour. of Phar. Jan.* 1824. *Ure's Dictionary.*

Substances somewhat allied to the preceding, but not alkaline.

Amygdalin.—A substance extracted in 1830 by Robiquet and Boutron—Charlard from the bitter almond.—*Ann. de Chim. et de Phys.* xliv. 352.

Asparagin.—Discovered by MM. Vauquelin and Robiquet, in the juice of the asparagus. It is deposited by evaporation in crystals, having the form of a rectangular octahedron, six-sided prism or right rhombic prism; has a cool and slightly nauseous taste; is soluble in water, and has neither an acid nor alkaline reaction.—*Ann. de Chim.* lvii. 88.

Bassorin was first noticed in gum *bassora* by Vauquelin. According to Gehlen and Bucholz, it is contained, together with common gum, in the gum tragacanth; and John found it in the gum of the cherry tree. Salep, from the experiments of Caventou, appears to consist almost totally of bassorin. It is characterized by forming with cold water a bulky jelly, which is insoluble in that menstruum, as well as in alcohol and ether; is not soluble in boiling water, except by long continued ebullition, when the bassorin at length disappears, and is converted into a substance similar to gum arabic.

Caffein was discovered in coffee by M. Robiquet, in 1821, and was soon after obtained from the same source by Pelletier and Caventou, without a knowledge of the discovery of Robiquet. It is a white crystalline volatile matter, which is soluble in boiling water and alcohol, and is deposited, on cooling in the form of silky filaments, like amianthus. It does not affect the vegetable blue colours, nor combine with acids.—*Jour. de Phar. for May,* 1826.

Cathartin.— The name has been applied by MM. Lassaigne and Feneulle to the active principle of senna. It is uncrystallizable, of a bitter nauseous taste, reddish yellow colour, and soluble in water and alcohol.—*Ann. de Chim. et de Phys.* xvi.

Chlorophyle.—A name applied by Pelletier and Caventou to the green colouring matter of leaves. It is prepared by bruising green leaves into a pulp with water, pressing out all the liquid and boiling the pulp in alcohol. The solution is mixed with water, and the spirit driven off by distillation, when the chlorophyle is left floating on the water.

Colocyntin.—This name is applied by Vauquelin to a bitter resinous matter extracted from colocynth, and to which he ascribes the properties of this substance.—*Brande's Jour.* xviii. 400.

Columbin.—Obtained from the Columbo root by M. Wittstock. It occurs in colourless prismatic crystals; is extremely bitter, inodorous, and without effect on vegetable colours; is soluble in about 30 or 40 parts of boiling alcohol, less so in cold alcohol, ether and water, yet the solutions are intensely bitter; is decomposed by nitric, sulphuric and muriatic acids, as well as by intense heat, without evolution of ammonia.—*Jour. of the Royal Institution,* ii. 631.

Conein, the active principle of the *Conium maculatum L.*, extracted by MM. Brandes and Geiseke, half a grain of which is said to have proved fatal to a rabbit, the symptoms being the same as those produced by strychnine.—*Brande's Jour. N. S.* iii. 227.

Cytisin.—A bitter purgative extractive matter similar to cathartin, found by Lassaigne and Chevalier in the *Cytisus alpinus.*

Dahlin is found in the Dahlia, or *Georgia* of botanists, and in the *Helianthus tuberosus, L* or Jerusalem artichoke. It is a white pulverulent substance, more soluble in hot than in cold water, and insoluble in alcohol; appears to have most analogy with starch and inulin. —*Layen, Ann. de Chim. et de Phys.* xxiv. 209. *Henry,* ii. 353.

Dracin.—A principle obtained from the gummi-resinous substance called *Dragon's Blood*, which has a slight affinity to the vegetable alkalies.—*Melandri, in Phil. Mag. and Ann.* ii. 394. *Henry,* ii. 363.

Fungin.—This name is applied by M. Braconnot to the fleshy substance of the mushroom. It is procured in a pure state by digestion in hot water, to which a little alkali is added; is nutritious in a high degree, and in composition is very analogous to animal substances; like flesh, it yields nitrogen gas when digested in dilute nitric acid.

Gentianin.—Obtained from the *Gentiana lutea* or gentian, about the same time, by M. Henry and M Caventou. It is yellow, inodorous, possessing strongly the aromatic bitterness of the gentian, more decidedly so however, when it is dissolved in an acid; it is highly soluble in ether and alcohol, from which it may be separated in the form of very small, yellow, needle-like crystals: does not sensibly change the colour of litmus when blue, or when reddened by acids, being apparently neutral; it does not possess any poisonous qualities.—*Magendie's Formulary,* 83.

Hematin.—The colouring principle of the *Hæmatoxylon campechianum*, or logwood. It occurs in small brilliant crystals, of a reddish-white colour, and slightly bitter, astringent and acrid taste; soluble in boiling-water, to which it gives an orange red colour.—*Chevreul, Ann. de Chim.* lxxxi. 129. *Brande's Jour.* xx. 389.

Imperatorin.—A crystalline principle resembling piperin, discovered by Osann in the root of the *Imperatoria Ostruthium.*

Inulin is a white powder like starch, which is spontaneously deposited from a decoction of the roots of the *Inula helenium* or *elecampane;* is insoluble in cold, and soluble in hot water, and is deposited from the latter as it cools, a character which distinguishes it from starch. With iodine it forms a greenish-yellow compound of a perishable nature. Its solution is somewhat mucilaginous; but inulin is distinguished from gum by insolubility in cold water, and in not yielding the saccholactic acid when digested in nitric acid.

Legumin is extracted from the pulp of ripe peas, by steeping in hot water. It is white, and when dried semi-transparent; forms a mucilage with tartaric acid; soluble in all alkalies and their carbonates.— *Einhof, in Ann. de Chim. et de Phys.* xxiv. 209. *Henry,* ii. 353.

Liriodendrin.—Discovered in the bark of the *Liriodendron tulipifera*, or American tulip-tree, by Professor J. P. Emmet, of Virginia.
When obtained from the alcoholic solution by spontaneous evapora-

tion it crystallizes in triangular and rhomboidal plates, interspersed with plumose or stellated prisms; some are perfectly limpid, others have the micaceous appearance of boracic acid; in this state it freely dissolves in alcohol; when gently heated the crystals fuse, slightly effervesce (owing to the escape of water,) and then become olive-coloured, without any appearance of crystallization on cooling; in the fused state the alcoholic solution is always olive green, and scarcely gives any indication of a regularly formed deposition, unless the alcohol employed is dilute.

The alcoholic solutions of both varieties possess an intensely bitter taste, but always leave the impression of heat upon the tongue.

The crystallized substance is solid, brittle and inodorous at 40°, fusible at 180°, and volatile at 270° F.; it is not acted on by weak acid or alkaline solutions, but is dissolved by concentrated sulphuric and nitric acid. According to Dr. Emmet, the properties of this substance appear to place it with camphor as a connecting link between the resins and volatile oils.—*Journal of the Philadelphia College of Pharmacy.*

Lupulin —A name given by Dr. Ansel W. Ives, to the active principle of the *Humulus lupulus*, or common hop. It is contained in all parts of the plant, but chiefly in the female flowers.— *Silliman's Jour.* ii. 302.

Madarin.—An extractive matter obtained by Dr. Duncan from the *Caloptris Madarii.*

Medullin.—This name was applied by John to the pith of the sunflower, but its existence as an independent principle is somewhat dubious. The term *pollenin* has been given by the same chemist to the pollen of tulips.—*Ann. of Phil.* vii. 49.

Olivile.—When the gum of the olive tree is dissolved in alcohol, and the solution is allowed to evaporate spontaneously, a peculiar substance, apparently different from the other proximate principles hitherto examined, is deposited either in flattened needles or as a brilliant amylaceous powder. To this M. Pelletier, its discoverer, has given the name of *Olivile.*—*Ann. of Phil.* xii.

Picrotoxin —Obtained by M. Boullay from the fruit of the *Cocculus suberosus* and *C. Plukenetti* of Decandolle. It occurs in four-sided prisms, of a silky lustre; it is inodorous but very bitter, has no alkaline reaction, nor does it neutralize acidity; it combines, however, with acids, and with the acetic and nitric acids forms crystallizable compounds.—*See M. Casaseca, in the Edin. Jour. of Science,* v. 184, *who shows that this cannot be ranked among the alkalies.*

Piperin is the name which is applied to a white crystalline substance extracted from black pepper. It is tasteless, and is quite free from pungency, the stimulating property of the pepper being found to reside in a fixed oil. [*Pelletier, in Ann de Chim. et de Phys.* xvi. *Carpenter, Sill. Jour.* xiii. 334.]   Dr. A. T. Thomson has extracted it from chamomile flowers.— *Turner.*

Plumbagin, extracted by Dulong from the root of the *Plumbago Europæa,* is soluble in water, alcohol and ether, and crystallizes from its solutions in acicular crystals of a yellow colour. Its aqueous solution is made cherry red by alkalies, subacetate of lead, and per-muriate of iron; but acids restore the yellow tint, and the plumbagin is found un-

altered. Its taste is at first sweet, but is subsequently sharp and acrid, extending to the throat.—*Brande's Jour. N. S.* vi. 191.

Polychroite.—The colouring matter of the *saffron*. It is of a deep yellow colour, deliquescent, readily soluble in water, but insoluble in pure sulphuric ether.—*Henry*, ii. 357.

M. Henry of Paris, attributes any medicinal activity of saffron to a volatile oil combined with the colouring matter.

Populin.—A substance found by Braconnot in the bark of the *Populus tremula*, analogous in properties and composition to Salicin, if not identical with it.

Rhubarbarin is the name employed by Pfaff to designate the principle in which the purgative property of the rhubarb resides. M. Nani of Milan, regards the active principle of this plant as a vegetable alkali; but he has not given any proof of its alkaline nature.— *Brande's Jour.* xvi. 172.

Salicin.—A peculiar compound obtained by M. Leroux from the bark of the *Salix alba, L.* or white willow. It is a perfectly white body which crystallizes in acicular prisms; has a very bitter taste; is soluble in about 20 parts of water at 60°, more soluble in hot, and to almost any extent in boiling water; is soluble also in alcohol, but not in ether, nor in any of the essential oils, except, perhaps, the oil of turpentine; when treated with sulphuric acid it assumes a fine red colour, perfectly resembling bichromate of potassa; with nitric acid it forms colourless solutions.—*Pelouze and J. Gay Lussac, in Phil. Mag. and Ann.* viii. 303.

From the trials which have been made with this substance in France, it appears to possess febrifuge powers scarcely inferior to those of the sulphate of quinine.

Gay Lussac and Magendie, who were appointed by the Academy of Sciences to examine the memoir of Leroux, conclude their report by stating, that this discovery is, without contradiction, one of the most important that has been made for many years in pharmaceutical chemistry.—*Ann. de Chim.* xliii. 440, *or Jour. of the Royal Institution*, i. 178.

Sarcocoll is the concrete juice of the *Penæa sarcocolla*, a plant which grows in the northern parts of Africa. It is imported in the form of small grains of a yellowish or reddish colour like gum arabic, to which its properties are similar. It has a sweetish taste, dissolves in the mouth like gum, and forms a mucilage with water. It is distinguished from gum by its solubility in alcohol, and by its aqueous solution being precipitated by tannin.—*See Thomson's Chemistry.*

Scillitin.—A crystalline principle discovered by Vogel in the *Scilla maritima.*

Suberin.—This name has been applied by M. Chevreul to the cellular tissue of the common cork, the outer bark of the cork-oak, (*Quercus suber,*) after the astringent, oily, resinous, and other soluble matters have been removed by the action of water and alcohol. Suberin differs from all other vegetable principles by yielding the suberic acid when treated with nitric acid.

Tiglin.— The active principle of *Croton-tiglium*—soluble in alcohol. —*Brande's Jour.* xx. 331.

Ulmin.—See *Ulmic Acid*, p. 377.

Zanthropicrite.—Extracted from the bark of a species of Zanthoxilum. It forms groups of greenish-yellow crystals, in silky divergent needles ; soluble in water and in alcohol, but not in ether ; it is distinguished by the circumstance, that solution of gold gives with it a precipitate which is quite insoluble in alcohol and in liquid ammonia. —*Chevallier and Pelletier, in Ann. de Chim. et de Phys. Feb.* 1827.—*Henry,* ii. 362.

Bitter Principle.—This name was formerly applied to a substance supposed to be common to bitter plants, and to be the cause of their peculiar taste. The recent discoveries in vegetable chemistry, however, have shown that it can no longer be regarded as a uniform unvarying principle. The bitterness of the *nux vomica*, for example, is owing to strychnine, that of opium to morphine, that of cinchona bark to cinchonine and quinine, &c. The cause of the bitter taste in the root of the squill is different from that of the hop or of gentian. The term bitter principle, when applied to any one principle common to bitter plants, conveys an erroneous idea, and should therefore be abandoned. *Turner.*

Extractive Matter.—This expression, if applied to one determinate principle supposed to be the same in different plants, is not less vague than the foregoing. It is indeed true that most plants yield to water a substance which differs from gum, sugar, or any proximate principle of vegetables, which, therefore, constitutes a part of what is called an *extract* in pharmacy, and which, for want of a more precise term, may be expressed by the name of *extractive.* It must be remembered, however, that this matter is always mixed with other proximate principles, and that there is no proof whatever of its being identical in different plants. The solution of saffron in hot water, said to afford pure extractive matter by evaporation, contains the colouring matter of the plant, together with all the other vegetable principles of saffron, which happen to be soluble in the menstrum employed.—*Turner.*

SECTION III.

SUBSTANCES WHICH, IN RELATION TO OXYGEN, CONTAIN AN EXCESS OF HYDROGEN.

Oils.

Oils are characterised by a peculiar unctuous feel, by inflammability, and by insolubility in water. They are divided into the fixed and volatile oils, the former of which are comparatively fixed in the fire, and, therefore, give a permanently greasy stain to paper ; while the latter, owing to their volatility, produce a stain which disappears by gentle heat.

Fixed Oils.—The fixed oils are usually contained in the seeds of plants, as for example, in the almond, linseed, rapeseed, and poppy seed ; but olive oil is extracted from the pulp which surrounds the stone. They are procured by bruising the seed, and subjecting the

pulpy matter to pressure in hempen bags, a gentle heat being general-
ly employed at the same time to render the oil more limpid.

Fixed oils, the palm oil excepted, are fluid at common temperatures,
are nearly inodorous, and have little taste ; are lighter than water,
their density in general varying from 0·9 to 0·96 ; they are mostly of
a yellow colour, and can be rendered nearly orquite colourless, by ani-
mal charcoal ; boil at or near, 600° F. suffering partial decomposition
at the same time, an inflammable vapour being disengaged even below
500° ; they burn in the open air with a clear white light, and are hence
employed for the purpose of artificial illumination. By exposure to the
air, these oils become *rancid*, in consequence of the acidification of the
mucilaginous matters which they contain ; they gradually also lose
their limpidity, and some of them, called on this account *drying oils*,
become so dry that they no longer feel unctuous to the touch, nor give
a stain to paper. This property, for which linseed oil is remarkable,
may be communicated quickly by heating the oil in an open vessel.
The drying oils are employed for making oil paint, and mixed with
lampblack constitute printer's ink.

Fixed oils do not unite with water, but by the aid of sugar or mu-
cilage may be suspended in it, so as to constitute an *emulsion ;* they
are sparingly soluble in alcohol and ether ; are thickened by sulphuric
acid, and also by chlorine ; are acted on with great energy by nitric
acid, giving rise, in some instances, to the production of flame ; they
unite also with the common metallic oxides, forming *varnishes* and
plasters ; they are readily attacked by alkalies, with ammonia, forming
a soapy liquid called *volatile liniment*, with the fixed alkalies, *soap*, the
inferior kind being made with potassa, and the hard with soda.

The fixed oils and fats are not pure proximate principles, but consist
of two substances, called by Chevreul, *Stearine* and *Elaine ;* the for-
mer of which is solid, and abounds in suet, butter and lard ; the latter
is fluid, and is found in greater quantities in oils. These substances,
however, entirely disappear in the formation of soap, being converted
into three compounds, to which M. Chevreul has applied the names of
Margaric and *Oleic* acids, and *Glycerine*. The two acids enter into
combination with the alkali employed, and the resulting compound is
soap. A similar change appears to be effected by the action not only
of the alkaline earths, but of several of the other metallic oxides.

Soap is decomposed by acids, and by earthy and most metallic salts.
On mixing muriate of lime with a solution of soap, a muriate of the
alkali is produced, and the lime forms an insoluble compound with the
margaric and oleic acids. A similar change ensues when a salt of
lead is employed.

From the analysis of Gay Lussac and Thenard it is probable that
olive oil consists of 1 Ox. 8+11 Hyd. 11+10 Car. 60=79.

REFERENCES. *The Memoirs of M. Chevreul are published in the Ann.
de Chim. et de Phys. of which the reader will find an abstract in Ure's
Chim. Dict. 4th ed. articles Elain and Fat. Lewis' Philosophical Com-
merce of the Arts, contains a history of Printer's Ink. On Soap, see
Aikin's Chem. Dict. Berzelius in his Traité de Chim. gives a very ela-
borate account of the fixed and volatile oils.*

Volatile or *Essential Oils*.—These substances, to which aromatic
plants owe their flavour, have a penetrating odour and acrid taste ; are
soluble in alcohol, though in different proportions ; scarcely soluble in

water; they are volatilized at a heat below 212° F. by which they may be distinguished from the fixed oils; they burn in the open air with a clear white light; are acted upon by strong nitric acid, with the evolution of light and heat; do not readily combine with alkalies or metallic oxides, but dissolve sulphur and phosphorus.

The most interesting of the essential oils are those of turpentine, caraway, cloves, peppermint, nutmeg, anise, lavender, cinnamon, citron, and chamomile. Of these the most important is the first, which is much employed in the preparation of varnishes, and for some medical and chemical purposes. It is procured by distilling common turpentine; and when purified by a second distillation, it is *spirit* or *essence* of turpentine. This oil cannot, without great difficulty, be dissolved in alcohol, though turpentine itself is easily soluble in that fluid. One part of the oil may be dissolved in seven parts of alcohol; but on standing awhile the greatest part of the oil separates and falls to the bottom. [*Ure*.] This compound gives a luminous flame when burned, and has been proposed as a substitute for oil and gas in artificial illumination. The purified oil, according to M. H. Labillardiére, contains no oxygen, but is composed of carbon and hydrogen in such proportions, that one volume of its vapour contains four volumes of olefiant gas, and two volumes of the vapour of carbon.—*Journal de Pharmacie*, iv. *For the analysis of some oils, by Dr. Ure and several other chemists, see his Dictionary, 4th ed. Art. Oil.*

Camphor.—An inflammable substance, closely allied to the essential oils, existing ready formed in the *Laurus Camphora, L.* of Japan, and in several other plants. It has a bitterish, aromatic, pungent taste, accompanied with a sense of coolness; it is unctuous to the touch and brittle, and may be easily reduced to powder by trituration with a few drops of alcohol; its specific gravity is 0·988; is very volatile, fuses at 288° and boils at 400 F.; it is insoluble in water, but freely soluble in alcohol, from which it is thrown down by water; is soluble also in the fixed and volatile oils, and in strong acetic acid; is converted by sulphuric acid into a substance resembling tannin; by nitric acid, into camphoric acid.

According to Dr. Ure it consists of 1 Ox. 8+9 Hyd. 9+10 Car. 60 =77. *Ure's Chem. Dict. Art. Camphor.*

Coumarin.—A name applied to the odoriferous principle of the Tonka bean, which is the produce of the *Dipteryx odorata, Willd.* It is white, of a hot pungent taste, and distinct aromatic odour; it crystallizes in four-sided prisms; is moderately hard, and is heavier than water; is sparingly soluble in water, but readily so in ether, alcohol, the fixed and volatile oils.

This substance appears to be nearly allied to the essential oils.—*Boullay and Boutron-Charlard, in Jour. de Phar. for* 1825. *Turner.*

Resins.

Resins are the inspissated juices of plants, and commonly occur either pure or in combination with an essential oil. They are solid at common temperatures, brittle, inodorous, and insipid; are non-conductors of electricity, and when rubbed become negatively electric; they are generally of a yellow colour, and semi-transparent; are fused by heat, and at a still higher temperature are decomposed; are soluble in alcohol, ether, and the essential oils, and, from the former, they

are precipitated by water, in which they are quite insoluble ; they are soluble also in pure potassa and soda, and are decomposed by the acids, the nitric forming with them a kind of tannin.

The most important of these substances are common resin, or *rosin*, copal, lac, sandarach, mastich, elemi and dragon's blood.

Resins are the bases of varnishes, and melted with wax and oil constitute ointments and plasters. Sealing wax is composed of lac, Venice turpentine and common resin.

The resins and gum resins have been much investigated and with great success by Unverdorben. In a series of very elaborate memoirs he has shown that many of the known resins are mixtures of several substances of the same class, which may in most instances be separated from each other by the action of alcohol and ether. And he has also shown that all the resins possess the power of forming salts with oxides in definite proportions and are therefore analogous to the acids.

REFERENCES. *Thomson on common Rosin, in Ann. of Phil.* xv. 468. *Hatchett's able investigations of the properties of the Resins will be found in the Phil. Trans. for* 1804, 1805, *and* 1806. *Ure's Chem. Dict. Art. Resin. Berzelius, Traité de Chim.* v.

Amber.—This substance is found plentifully in beds of bituminous wood in some parts of Prussia. It is undoubtedly of vegetable origin, and has the general properties of a resin, but is distinguished by yielding succinic acid, when heated in close vessels.—*For details concerning this substance, see Ure's Chem. Dict.*

Balsams.—The balsams are native compounds of resin and benzoic acid, and issue from incisions made in the trees which contain them, in the same manner as turpentine from the fir. Some of them, such as storax and benzoin, are solid ; while others, of which the balsams of Tolu and Peru are examples, are viscid fluids.

Gum-Resins.—The substances to which this name is applied are the concrete juices of certain plants, and consist of resin, essential oil, gum, and extractive vegetable matter. The two former principles are soluble in alcohol, and the two latter in water. Their proper solvent, therefore, is proof spirit. Under the class of gum-resins are comprehended several valuable medicines, such as aloes, ammoniacum, assafœtida, euphorbium, galbanum, gamboge, myrrh, scammony and guaiacum.—*Hatchett, in Phil. Trans.*

Caoutchouc, commonly called elastic gum, or Indian rubber, is the concrete juice of the *Siphonia elastica, Pers.* a native of Brazil, and of several East India trees, as the *Ficus indica*, &c. The most remarkable property of this substance is its elasticity. It is inflammable, and burns with a bright flame ; is not soluble in water, but may be dissolved, though with difficulty, in pure ether ; it is soluble in petroleum, cajeput oil, purified naptha, and the oil of sassafras ; it loses its elasticity by the action of alkalies.

This substance is employed for forming varnishes, for covering cloth so as to render it impervious to moisture, &c.

Dr. J. K. Mitchell, of Philadelphia, has discovered a mode of making sheet-caoutchouc, which possesses very singular properties.

By the destructive distillations of Caoutchouc Dr. W. Gregory obtained a peculiar volatile liquid.—*See Lond. and Edin. Phil. Mag.* ix. 321.

REFERENCES. *For a notice of the solubility of Caoutchouc in cool naptha, see Ann. of Phil.* xii. *Dr. Mitchell's discovery is described in the Journal of the Phil. College of Pharmacy, for Jan.* 1830, *and in a note to Turner's Chem. by Dr. Buche. Faraday on pure Caoutchouc, and the substances by which it is accompanied in the state of sap or juice, Brande's Jour.* xxi. 19. *Besides Chemical examinations, this paper contains a list of the most important memoirs on this curious substance. Caoutchouc found in Arkansas, Sill. Jour.* iii. 44.

Wax.--This principle exists in many plants, and especially in the berries of the *Myrica Cerifera, L.* In its common form it is always more or less coloured, but when pure is colourless and insipid, its specific gravity is 0·96° it is solid at ordinary temperatures, and somewhat brittle, but may be easily cut with a knife, when it exhibits a peculiar appearance, called the waxy lustre ; it is insoluble in water, sparingly soluble in boiling alcohol and ether ; it is readily soluble in the fixed oils when assisted by heat, and forms a compound of variable consistence, which is the basis of *cerates* and *ointments ;* it melts at about 150° F. and at a higher temperature it is converted into vapour ; when burned in contact with air it yields a clear white light, and is hence employed for forming candles.

According to Dr. John, wax consists of two portions, one of which is soluble in alcohol, the other is insoluble. To the former he has given the name of *Cerin,* and to the latter that of *Myricin.* According to the analysis of Dr. Ure, it consists of 1 O. 8+11 H. 11+13 C. 78=97.

REFERENCES. *Ure's Chem. Dict. Thenard, Traité de Chim. Dana's chemical examination of the berries of Myrica Cerifera, Sil. Jour.* i. 294. *Brande's analysis of Vegetable Wax from Brazil, Phil. Trans.* 1811, 267. *For the process of bleaching wax, see Aikin's Chem. Dict. art. Wax.*

Alcohol.—Atom. Num. 23— *Symb.* $(2H+C2)+(O+H.)$

This principle does not exist ready formed in plants, but is the product of vinous fermentation, and is the intoxicating ingredient of all spirituous and vinous liquors.

PROPERTIES. Alcohol is considerably lighter than water. The lightest that can be obtained by simple distillation has a specific gravity of 0·825, but by the intervention of substances that strongly attract water, it has been brought to the specific gravity of 0·796 at 60° F. It is a colourless fluid, of a penetrating odour, and burning taste : is highly volatile, boiling when its density is 0·820, at 176° F. ; it is highly inflammable, and burns with a yellowish blue flame, the colour of which varies somewhat with the strength of the alcohol, and it leaves no residuum, being converted into carbonic acid and water ; it is remarkably expansible by heat ; at 50° F. it gives a gas, the density of which is to that of the atmosphere as 1·613 is to 1 ; it unites in all proportions with water, the combination being usually attended with a diminution of volume and an increase of temperature ; it dissolves few of the salifiable bases, but all the deliquescent salts are soluble in it, except carbonate of potassa, and they form with it definite compounds, analogous to the hydrates, which have been called *Alcoates ;* it dissolves also many vegetable principles, as resins, camphor, the essential oils, &c. ;

and it has never been congealed by any known method of producing artificial cold.

Congelation of Alcohol.—Common spirits freeze in severe cold.— But absolute alcohol did not congeal when it was exposed by Mr. Walker to a cold of —90°· Professor Leslie, it is believed, exposed it to a cold of —120° without observing any congelation. M. Bussy of Paris succeeded by means of liquid sulphurous acid, in congealing alcohol of sp. gr. 0·85. The temperature was —90°.—*See Thomson on Heat, &c.* 171.

PREPARATION, &c. Common alcohol, or *Spirit of Wine,** is prepared by distilling whiskey or some ardent spirit, and the rectified spirit of wine is procured by a second distillation. The first has a specific gravity of about 0·867, and the last of about 0·835 or 0·84. In this state it contains a quantity of water, from which it may be freed by mixing it with about one-fourth of its weight of dry and warm pearlash, chloride of calcium, or some other substance which has a strong affinity for water, and subsequent distillation at a low heat. But a more easy and elegant process for concentrating alcohol, is that of placing it with powdered quicklime under the receiver of an air-pump, as proposed by Mr. Graham. The alcohol obtained by the preceding processes is called *Absolute*, on the supposition of its being quite free from water.

The strength of alcohol can be determined by its specific gravity, and tables are constructed, showing the specific gravity of various mixtures of alcohol and water. Equal weights of absolute alcohol and water constitute *Proof Spirit*, the density of which is 0·917; but the proof spirit employed by the colleges for tinctures, has a specific gravity of 0·930 or 0·935.— *Turner.*

Alcohol in Wine.—It has been a subject of some controversy among chemists whether alcohol exists *ready formed* in wine or whether it is *generated* by the heat employed in the distillation. The latter opinion was supported by Fabroni; [*Ann. de Chim.* xxx. 220,] but its fallacy has been completely exhibited by the able investigations of Mr. Brande, and Gay Lussac.

The existence of alcohol *ready formed* in wines and other fermented liquors, is evident from the following considerations.

1. Alcohol can be obtained from wines by distillation *in vacuo* at the temperature of 60° F., which precludes the idea that it is formed by the action of heat upon the elements existing in the fermented liquor. —*Gay Lussac. Thenard, Traité de Chim.*

2. When a portion of wine is partly distilled off and the distilled liquor is afterwards added to the residuum in the retort, the specific gravity of the mixture is precisely the same as that of the wine previous to distillation. I confirmed the statement of Mr. Brande on this point in the case of three kinds of wine. Alcohol, being much lighter

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* Spirit of Wine was known to Raymond Sully in the 13th century, and distinguished by him by the names of *aqua vitæ ardens*, and *argentum vivum vegetabile*. He knew the method of rendering it stronger by an admixture of dry carbonate of potash and of preparing vegetable mixtures by means of it.— *Thomson's History of Chemistry.*

than wine, if it was formed during the process of distillation would
have the effect of reducing the specific gravity when added to the
residuum, which is never the case.

3. When the colouring and extractive matters in the wine are pre-
cipitated by sub-acetate of lead, the pure alcohol may be separated by
the subsequent addition of dry sub-carbonate of potash, in the same
manner, as from whiskey, gin and brandy.—*Brande.*

It may, therefore, be considered as satisfactorily proved that alcohol
exists, *as such*, in wines and other fermented liquors; but there is still
much doubt whether their *intoxicating* powers are not materially
modified by the acid and other vegetable matters which they contain.

A few years since I analyzed several varieties of wines and other
liquors, chiefly for the purpose of ascertaining the amount of alcohol
which they contained. The process adopted was that of slow and
careful distillation, and the accurate determination of the specific grav-
ity of the distilled liquor. In the following table of my results, the
kind of liquor is designated and the proportion of alcohol per cent. *by
measure* which they were found to contain, is stated. And in order
that the strength of these liquors may be easily compared with that of
those examined by Mr. Brande, I have taken as the standard, alcohol
of the specific gravity of 0·825 at the temperature of 60° F.

Table *of the proportion of Alcohol per cent.* by measure, *contained in several kinds of Wine and other Liquors ;—the specific gravity of the standard Alcohol being* 0·825 *at the temperature of* 60° F.

Kind of Liquor.	Proportion of Alcohol pr.ct. by measure.	Kind of Liquor.	Proportion of Alcohol pr.ct. by measure.
1. Madeira (common,)	25.77	21. Torres Vedras,	20.51
2. Do. (imported from the house of Robt. Seal,)	23.11	22. Sauterne,	13.00
3. Do. (common,)	22.41	23. Claret, (Chateau Margeaux,)	11.80
4. Do. imported from the house of Houghton & Co.	22.25	24. Do. (Palmer Margeaux,)	11.04
5. Do. ("Farquhar," in bottle 40 years,)	21.79	Average,	11.42
6. Do. (20 years old,)	21.45		
7. Do. ("Edgar,")	21.30	25. American Wine, (2 years old,)	11.25
8. Do. ("Brammin,")	20.91	26. Metheglin, 20 years in bottle,	10.57
9. Do. (common,)	20.72		
10. Do. ("Wanderer,")	20.70	27. Ale, (Albany, in bottle 2 years,)	10.67
11. Do. ("Blackburn," old,)	20.68	28. Do. (Albany, in barrel,)	7.38
12. Do. (said to be the pure juice, 28 years old,)	19.30	29. Cider, (in bottle,)	4.80
13. Sercial Madeira,	25.18	30. Do. (in barrel, 6 months,)	4.84
14. Do. Do.	18.96	31. Do. (in barrel,)	4.41
Average of 14 kinds,	21.75	Average,	4.68
15. London Particular,	22.10	32. Irish Whiskey, (imported in 1825,)	73.70
16. Bucellas,	18.80	33. Gin (genuine "Hollands")	55.44
17. Brown Sherry,	18.03	34. Brandy, (common.)	51.01
18. Port, (7 years in bottle,)	22.87	35. Whiskey, (common.)	42.84
19. Do.	22.35	36. Spirits of Wine, (obtained at the druggists,)	93.27
20. Do.	21.98	37. Do.	95.35
Average,	22.60		

The results in the above table agree generally with those of Mr. Brande. In all cases where the difference was marked, the trials were repeated several times, and the mean of these is stated. This was particularly so with Nos. 13 & 14, 22, 23 & 24. The ale, No. 27, contains more alcohol than any put down in the table of Mr. Brande as ordinarily published; but in the Journal of Science and the Arts, (*Vol.* 5, *p.* 124) he states that Lincolnshire Ale, brewed by Sir Joseph Banks, contained 10·84 per cent. of alcohol. Our cider it would seem contains less alcohol than the lowest average of the specimens examined by Mr. Brande, which is 5·21 per cent.

-REFERENCES. *For a table of the specific gravities of Alcohol of different strength, see Henry's Chem.* ii. 373. *Graham on the concentration of Alcohol, in Edin. Phil. Trans.* 1828. *On the concentration of Alcohol by bladders, Brande's Jour.* xviii. 180. *Graham on the Alcoates, Brande's Jour. N. S.* iv. 442. *On Alcohol in wines, see Thenard, Chaptal on Wine, and Murray's Chem. For Brande's table of the quantity of Alcohol in various wines, &c. see his Manual of Chemistry or Pharmacy. The experimental details are published in Phil. Trans. for* 1811 *and* 1813. *The article distillation in the Supplement to the Ency. Britannica, by Dr. Thomson. Henderson on Wines.*

Ether.

The name *Ether* was formerly employed to designate the volatile inflammable liquid which is formed by heating a mixture of alcohol and sulphuric acid ; but the same term has since been extended to several other compounds produced by the action of acids on alcohol, and which, from their volatility and inflammability, were supposed to be identical or nearly so with sulphuric ether.

M. Boullay, sen., divides the ethers into three classes ; 1st. Those obtained by acting upon alcohol with sulphuric, phosphoric and arsenic acids, which are identical ; 2dly. Those produced by the combination of hydro-carbon with certain hydracids ; 3dly. Those which, according to the experiments of Thenard and of Boullay, are constituted of alcohol and an oxacid.

Ethers of the First Class.

Sulphuric Ether.—Atom. Num. 37—*Symb.* 2 (2H+2C)+(O+H.)

A colourless fluid, of a hot pungent taste, and fragrant odour ; its specific gravity in its purest form, is about 0·700, and according to Lowitz, 0·632, but the ether of the shops is seldom less than 0·750, owing to the presence of alcohol ; it is extremely volatile, a few drops poured on the hand evaporating instantly with the production of cold ; when of the specific gravity of 0·713, it boils at 92°·2 F. under the pressure of the atmosphere, [*Dumas and Boullay*,] and *in vauco* at 20° below 0 ; at 46° below zero it is congealed ; its vapour has a density of 2·586 compared to air as 1 ; it combines with alcohol in all proportions, but not with water ; it is highly inflammable, burning with a blue flame, and forming carbonic acid and water ; and with oxygen gas its vapour forms an explosive mixture ; it may be decomposed by being passed through a red hot porcelain tube ; it dissolves many of the resins and essential oils, and some of the vegetable alkalies, and when breathed produces effects similar to those produced by nitrous oxide ; but this is sometimes attended with danger.—*See Brande's Jour.* iv. 159.

Action of Water.—When ether is agitated with that fluid, the greater part separates on standing, a small quantity being retained, which imparts an ethereal odour to the water ; the ether so washed is very pure, because the water retains the alcohol with which it is mixed.

Action of Platinum.—When a coil of platinum wire is heated to redness, and then suspended above the surface of ether contained in an open vessel, the wire instantly begins to glow, and continues in that

state until all the ether is consumed. During this slow combustion, pungent acrid fumes are emitted, which Mr. Daniel considered as a new acid, and described under the name of *Lampic Acid ;* but he has since ascertained that its acidity is owing to the acetic acid, which is combined with some compound of carbon and hydrogen, different both from ether and alcohol.—*Brande's Jour.* vi. and xii.

If platinum sponge be heated and put into the vapour of ether, it becomes red hot, and continues so as long as any of the vapour is unconsumed. According to Dr. Thomson, powdered black oxide of manganese, oxide of nickel, oxide of cobalt, oxide of uranium, oxide of tin, &c. when in the loose and porous state in which they are produced by decomposing the oxalates of the several metals by heat in the open air, may be substituted for platinum.— *Thomson on Heat, &c.*

Action of Light.—If ether is exposed to light in a vessel partially filled, and which is frequently opened, it gradually absorbs oxygen, and a portion of acetic acid is generated. This change was first noticed by M. Planche, and has been confirmed by Gay Lussac. M. Henry, of Paris, attributes its developement to acetic ether, which he believes to be always contained in sulphuric ether.— *Turner.*

PREPARATION. Ether may be made by mixing gradually equal parts of strong sulphuric acid and alcohol, and subjecting the mixture to slow distillation, into a receiver surrounded by ice, by a carefully regulated heat. The ether which first passes over is impure, being contaminated with alcohol and with sulphurous acid. To separate these impurities, it should be agitated with a strong solution of potassa, which neutralizes the acid, while the water unites with the alcohol.ꞏ The ether is then distilled by a very gentle heat, and may be rendered still stronger by distillation from the chloride of calcium.

Sulphovinic Acid is a peculiar acid formed during the preceding process, and which, according to Mr. Hennel, is composed of sulphuric acid and carburet of hydrogen.—*Phil. Trans.* 1826, 247, *or Brande's Jour.* xxi. 331.

Phosphoric Ether is very volatile ; boils at 100° F. ; is soluble in eight or ten parts of water, and burns with a white flame. It is obtained by distilling a mixture of thick tenacious phosphoric acid and alcohol.— *Boullay, Ann. de Chim.* lxii. 192.

Ethers of the Second Class.

Muriatic Ether.—This compound is highly inflammable and volatilizes still more rapidly than sulphuric ether ; when burned it gives out muriatic acid gas. It may be obtained by distilling equal measures of alcohol and concentrated muriatic acid.

Chloric Ether, Hydriodic Ether, Fluoric Ether, and *Fluoboric Ether* may also be obtained by processes analogous to those already described.—*See Henry's Chem.* ii. 395.

Ethers of the Third Class.

Nitric Ether.—This substance agrees with sulphuric ether in its leading properties, but it is still more volatile ; it usually reddens litmus, and though this property may be destroyed by a little lime, it
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soon becomes acid by keeping; it is highly combustible at common temperatures, and under ordinary pressure the specific gravity of its vapour is 2 628. It is prepared by distilling a mixture of concentrated nitric acid with an equal weight of alcohol; but the process requires great care.

Sweet Spirits of Nitre, is a solution of nitric ether in alcohol. When pure it is colourless, possesses a peculiar odour and a specific gravity of 0·850. It reddens litmus feebly, and volatilizes without leaving any residue. The presence of muriatic and sulphuric acids may be detected by diluting it with a sufficient quantity of water, and adding solution of nitrate of silver and chloride of barium.

Acetic Ether.—This compound is volatile; has a specific gravity of 0·866, being heavier than most other ethers; it burns with a yellow-ish-white flame, and during its combustion acetic acid is developed.— It is formed by distilling 12 or 15 times in succession concentrated acetic acid (procured from acetate of copper) with alcohol, and return-ing the distilled liquor to charge the retort.

REFERENCES. *Thomson's System of Chem. Thenard, Traité de Chim. Henry's Chem.* ii. 383. *Brande's Manual of Pharmacy. Daniell on Lampic Acid and the Lampates, Brande's Jour.* vi. 318. *Hare's descrip-tion of an aparatus for preparing Nitric Ether, Sill. Jour.* ii. 326. *Dalton's Memoir on Sulphuric Ether, Ann. of Phil.* xv. 117. *Thenard on the action of Vegetable Acids on Alcohol, Mem. d'Arcueil,* ii. 5, *or Phil. Mag.* xxxvii. 216. *Dumas and Boullay, Ann. de Chim. et de Phys. Jan.* 1828.

Bituminous Substances.

Under this title are included several inflammable substances, which, though of vegetable origin, are found in the earth, or issue from its surface. They may be conveniently arranged under the two heads of bitumen and pit-coal. The first comprehends naphtha, petroleum, mineral tar, mineral pitch, asphaltum, and retinasphaltum, of which the three first mentioned are liquid, and the others solid. The second comprises *brown coal*, the different varieties of *common* or *black coal*, and *glance coal*.

Bitumen—Naphtha.—A volatile limpid liquid, occurring in some parts of Italy, and on the banks of the Caspian sea; and produced also by distillation from petroleum. It has a strong peculiar odour, and light yellow colour; its specific gravity, when highly rectified, is 0·753 at 61° F.; it is very inflammable, and burns with a white flame mixed with much smoke; at 186° F. it enters into ebullition, and its vapour has a density of 2·833; it contains no oxygen, and is hence employed for protecting the more oxidable metals, as potassium and sodium, from oxidation.

Petroleum, found in several parts of the world, especially in coal dis-tricts, is of a reddish-brown colour, unctuous to the touch, and less lim-pid than naphtha. *Mineral tar* is very similar to petroleum, but is more viscid and of a deeper colour. From the petroleum of Rangoon Dr. Christison has obtained a white, pearly, crystalline, inflammable substance, to which he has given the name of *petroline.*

Asphaltum is found on the banks of the Dead sea, and occurs in large

quantity in Barbadoes and Trinidad. It is solid, brittle, of a black colour, vitreous lustre and conchoidal fracture ; it melts easily, and is very inflammable.

Mineral Pitch or *Maltha* is likewise a solid bitumen, but is much softer than asphaltum. The elastic bitumen, or *Mineral caoutchouc*, is a rare variety of mineral pitch, found only in the Odin mine, near Castleton, in Derbyshire, England.

Retinasphaltum is a peculiar bituminous substance, found associated with the brown coal of Bovey in Devonshire, and described by Mr. Hatchett. It consists partly of bitumen, and partly of resin, a composition which led Mr. Hatchett to the opinion that bitumens are chiefly formed from the resinous principle of plants.—*Phil. Trans.* 1804.

Pit Coal.—This is a general term often applied to several varieties, and even distinct species. *Brown coal* is characterized by burning with a bituminous odour. It sometimes has a fibrous structure, and hence this variety is called *bituminous-wood*. *Pitch coal* or *jet*, which is employed for forming ear-rings and other trinkets, is intermediate between the brown and black coal. *Black* or *common coal*, of which there are several varieties, is extensively employed for fuel.

Glance Coal or *Anthracite*, abundant in Pennsylvania, differs from common coal in containing no bituminous substances, and in not yielding inflammable gases by distillation. It is nearly pure carbon, and consequently it burns without flame.

REFERENCES. *For localities of the Bitumens above noticed, and further information concerning them, see Cleaveland's Mineralogy. Thomson on the composition of different species of Pit Coal, Ann. of Phil. xiv. 81. Ure's analysis of Splint and Cannel Coal, Phil. Trans. 1822, 471. Karsten's observations and experiments on different kinds of Coal ; a very valuable treatise, of which an abstract will be found in Jameson's Edin. New Phil. Jour. ii. 280, and iii. 60, 322.*

SECTION IV.

SUBSTANCES, THE OXYGEN AND HYDROGEN OF WHICH ARE IN EXACT PROPORTION FOR FORMING WATER.

Sugar.

Sugar is an abundant vegetable product, existing in a great many ripe fruits, in the juice of the maple, *Acer Saccharinum, L.* in the beet root, &c. But the plant which contains it in the greatest quantity is the sugar cane, from which nearly all the sugar used in this country is obtained. When pure, sugar is a white crystalline substance, of a purely sweet taste, and without odour ; it is easily soluble in cold water, and in almost any proportion in hot, the solution constituting *syrup*, which, by long repose deposits crystals of sugar ; it is soluble in alcohol, and large crystals may be obtained from the alcoholic solution ; it combines with alkalies and alkaline earths, forming compounds, in which the taste of the sugar is greatly injured, but which may be restor-

ed by the addition of an acid; when triturated with oil it forms a mixture which is diffusible through water, producing a milky fluid, called an *emulsion*; when exposed to the action of nitric acid it is converted into oxalic acid.

Manna, Sugar of Grapes, of the Maple, of Beets, &c. are varieties of sugar, and possess the same general properties. *Honey* consists principally of a crystallizable and an uncrystallizable sugar. *Molasses* is an uncrystallizable sugar.

REFERENCES. *For detailed accounts of the manufacture of Sugar, see Edward's History of the West Indies; and Aikin's and Ure's Chem. Dict. For papers on the making of Sugar from Beets, see Repert. of Arts. 2d ser.* i. vii. xxii. xxviii. xxix. xl. *Chaptal on the same subject, Ann. de Chim.* xcv. 253, *or Ann. of Phil.* ix. 50. *On the same subject, see also Franklin Jour.* ii. 183. *Howard's celebrated process for preparing and refining Sugar, are fully described in the Repert. of Arts,* xxiii. 129, xxv. 257. *On the composition of Sugar, see Prout's Essay on Alimentary Substances, Phil. Mag. and Ann.* iii. 98.

Starch or Fecula.

Starch exists in a great variety of vegetables, being one of the chief ingredients of most kinds of grain, and of some roots, as the potatoe, from which it may be extracted by diffusing the powdered grain or rasped root in cold water, and separating the grosser parts by a strainer. It is a white pulverulent substance, without taste or smell; it is insoluble in alcohol, ether or cold water, but is easily dissolved in boiling water; it forms a blue colour with iodine, by which it may be distinguished from all other substances; it unites with alkalies, forming a compound, soluble in water, from which the starch is thrown down by acids; is decomposed by strong sulphuric acid, and by nitric acid, assisted by heat, is converted into oxalic and malic acids.

Amidine, a term applied to torefied starch—that is, starch modified by heat, whether in the dry way or by boiling water. It yields a blue colour with iodine, and is soluble in cold water.

Hordein.—A name given by Proust to a peculiar principle contained in barley, which he supposed to be converted, in malting, partly into starch, and partly into sugar. Dr. Thomson, however, considers it merely a modification of starch.

According to Caventou, *Indian arrow root,* prepared from the root of the *Maranta arundinacea, L.,* has all the characters of pure starch. *Sago,* obtained from the pith of an East Indian palm tree, *Cycas circinalis, L.* and *Tapioca,* from the root of the *Jatropa manihot, L.* (*Janipha manihot, Kunth,*) are chemically the same substance. They both exist in the plants from which they are extracted, in the form of starch; but as heat is employed in their preparation, the starch is more or less converted into amidine. From this it follows that pure potatoe starch may be used instead of arrow root, and that the same material, modified by heat, would afford a good substitute for sago and tapioca.— *Turner.*

REFERENCES. *Skrimshire on the quantity of Starch in the different varieties of Potatoe, and the methods of separating it, Nicholson's Jour.*

xxi. *Pearson's experiments and observations on Potatoe Starch, Repert. of Arts, 1st Ser.* iii. 383. *Lampadius' analysis of four different varieties of Potatoe, Ann. of Phil.* v. 39. *For a notice of the papers of Saussure, Guibourt, Caventou, and others, see Henry's Chem.* ii. 272. *Prout's essay on alimentary substances, Phil. Mag. and Ann.* iii. 98.

Gum.

Of this proximate principle *Gum Arabic* may be taken as an example. It is the concrete juice of several species of *Mimosa* or *Acacia*, natives of Africa and Arabia. It occurs in small rounded, transparent, friable grains, commonly of a pale-yellow colour, inodorous and nearly tasteless ; it is soluble in water ; and forms a solution called *mucilage ;* is insoluble in alcohol and ether, and the former precipitates it from its solution in water ; is soluble in alkaline solutions and in lime water, and is precipitated unchanged by acids; is decomposed by dilute acids, and by the action of strong nitric acid is converted into *Mucic* or *Saccholactic Acid ;* it is not altered by exposure to the air, but its solution at length becomes sour and gives out an odour of acetic acid ; it is precipitated from its solution by several matallic salts, especially sub-acetate of lead.

Besides gum arabic, there are several well marked kinds of this principle, especially the gum tragacanth, cherry-tree gum, and the mucilage from linseed, each of which presents some peculiarities.

REFERENCES. *For a good Account of the production and gathering of Gum Arabic, see Aikin's Chem. Dict. art. Mucilage. For various analyses of Gum, by Ure and others, see Henry,* ii. 209. *Bostock on Vegetable Jelly, Nicholson's Jour.* xviii. 28. *For a notice of several varieties of gum and vegetable mucilage. See Berzelius, Traité de Chim.* v. 214.

Lignin.

The *woody fibre* which remains after the action of water and alcohol on wood, has been called *lignin.* It is insipid and inodorous, undergoes no change by keeping ; by the action of sulphuric acid it is converted into a substance like gum, and by diluted sulphuric acid this is converted into sugar ; by destructive distillation it yields *Pyroligneous acid,* and a bright shining charcoal remains.—*See the references under Acetic Acid.*

SECTION V.

SUBSTANCES WHICH, SO FAR AS IS KNOWN, DO NOT BELONG TO ANY OF THE PRECEDING SECTIONS.

Colouring Matter.

The *Colouring Matter of Vegetables* does not appear to reside in any peculiar principle, and is therefore differently affected by solvents. By the affinity of certain solvents, colouring matter is separated from vegetables, and by the superior attraction of silk, wool, cotton, &c. it is separated from the solvents and attracted to the fibres of the fabric.

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Colours which are fixed and durable, by the simple attraction of the fibres of cloth, without the intervention of any other substance, are called *Substantive Colours*. Those which require the intervention of a third body, which possesses an attraction both for the cloth and the colouring matter, and thus links them together, are called *Adjective Colours*. The substance which possesses the property of fixing colours, is called a *mordant* or *basis*. The mordants in most common use are alumina, oxide of iron and oxide of tin. Alumina has a very strong attraction for colouring matter, and forms insoluble compounds, called *lakes*.

Though there is a great variety in the tints observable in dyed stuffs, they may all be produced by four simple ones, viz. blue, red, yellow and black.

Blue Dyes.—The most important of these is *Indigo*, the produce of several species of *Indigofera*. It is a brittle substance, of a deep blue colour, and without either taste or odour; when heated to $550°$ F. a fine violet vapour arises, which condenses into acicular crystals, called *Indigogene*. [*Gorham, in N. Eng. Jour.*] It is soluble in concentrated sulphuric acid, and the solution forms the *Saxon Blue*; it contains oxygen in its natural state, and when deoxidized has a green tint, and is then soluble in alkalies, and may be fixed on cloth, which acquires the blue colour by exposure to the air.

The indigo of commerce is of a very complex nature, containing, according to Berzelius, in addition to the salts of magnesia and lime, the following ingredients:—1. A glutinous matter; 2. Indigo-brown; 3. Indigo-red; 4. Indigo-blue.

Cerulin and *Phenicin*, are two compounds of indigo and water, described by Mr. Crum; but Berzelius supposes them to be of a more complicated nature.—*See Crum on Indigo and on certain substances produced from it by means of Sulphuric Acid, Ann. of Phil.* xxi. 81.

Red Dyes.—The chief substances which are employed for giving the red dye, are *Cochineal*, an insect feeding upon several varieties of *Cactus*; archil, the produce of the *Parmelia roccella, Ach.*, a lichen growing in the Canary Islands; madder, the root of the *Rubia tinctorum, L.*; Brazil-wood, or the wood of the *Cæsalpinia echinata, Lam.*; logwood, or that from the *Hæmatoxylon campechianum, L.* of tropical America; and safflower, or the dried flowers of the *Carthamus tinctorius, L.* These are all adjective colours.

The blue pigment called *Litmus* or *Turnsol*, used as a test, is a compound of the red matter of the archil and an alkali. *Cudbear* is an article of a similar kind manufactured at Glasgow. It is used in dying, and as a chemical test.

Yellow Dyes.—The chief of these are the quercitron, or *Quercus tinctoria, W.*; several species of American hickory; turmeric, or the root of the *Curcuma longa, L.*; fustic, or the wood of the *Morus tinctoria, L.*, of the West Indies; all adjective colours.

Black Dyes.—The black dye is made of the same ingredients as writing ink; and therefore consists essentially of a compound of oxide of iron, with gallic acid and tannin. By the addition of logwood and acetate of copper, the black receives a shade of blue.

REFERENCES. *For full details on the subject of Dying, &c., See Berthollet on Dying; Bancroft's Researches on Permanent Colours, Calico-*

Printing, &c. ; Dr. T. Cooper on the same ; Parkes' Chem. Essays, ii. 63 ; *a paper by Mr. Henry, in the third volume of the Manchester Memoirs ; and the Essay of Thenard and Roard, in Ann. de Chim.* lxxiv. *For account of the recent Researches of Berzelius, Liebig, &c. on Indigo, see Henry's Chem.* ii. *or Berzelius, Traité de Chim.*

Tannin.

This substance exists in large quantity in the excresences of several species of the oak, called *gall-nuts*, and also in the bark of several trees, and in many other vegetables. It is difficult to obtain it in a pure state, and hence its nature and composition are still obscure. In its dry state it is a brown friable substance, of a resinous fracture, insoluble in pure alcohol, but soluble in water ; its aqueous solution has a brown colour, and is said not to become mouldy by keeping ; it has a strong attraction for alkalies, forming compounds which are, for the most part, sparingly soluble in water ; it is precipitated from its solution by most of the acids, and by alkaline bases.

The most characteristic property of tannin is its action upon the salts of the peroxide of iron and solution of gelatin. With the former it causes a black precipitate ; with the latter an insoluble yellowish precipitate, called *tanno-gelatin,* which is the essential basis of leather, being always formed when skins are macerated in an infusion of bark.

Artificial Tannin.—A very interesting substance, discovered by Mr. Hatchett, and obtained by the action of nitric acid on animal or vegetable charcoal, and several other substances. It is a brown fusible substance, of a resinous fracture and astringent taste ; is soluble in cold water, reddens litmus, and acts like natural tannin upon salts of iron and solution of gelatin.

REFERENCES. *Sir H. Davy on the process of Tanning, Repert. of Arts,* 2d. ser. iii. 435. *The article Tannin in Ure's Chem. Dict.* 4th. ed. *contains a Table of the proportion of Tannin in different Vegetable Products, compiled from the experiments of Sir H. Davy, Biggins and Cadet de Gassincourt. Aikin's Chem. Dict. Art. Leather and Gelatin, contains an account of the process of Tanning. Hatchett, on Artificial Tanning, Phil. Trans.* 1805 *and* 1806, *or Repert. of Arts,* 2d. ser. viii. *and* x.

Gluten—Yeast—Vegetable Albumen.

Gluten.—This is obtained from wheat flour, by making it into a paste and kneading it under a small stream of water. The fluid becomes milky, carries off the starch, and gluten remains. It is of a grayish colour, fibrous structure, tough and elastic, and when stretched into thin pieces, appears like animal membrane ; it has scarcely any taste ; is insoluble in water, alcohol and ether ; it is soluble both in acids and alkalies ; when kept in a warm and moist situation it ferments, and becomes acid, but in a few days putrefies, and gives out an offensive odour, like that of putrifying animal matter ; during its putrefaction two new substances are formed, called by Proust *Caseous Oxide* and *Caseic Acid,* identical with the principles which are generated during the fermentation of the curd of milk.

Gluten is contained in most grains, and it is the most nutritive of all

vegetable substances. To this, wheat flour owes its property of forming a tenaceous paste with water, and the carbonic acid evolved during the fermentation of dough, producing what is called the *rising* of the dough, is detained by the viscid gluten, and thus forms light, spongy bread.

There appear to be two distinct principles in gluten, called by M. Taddei, the discoverer, *Gliadine* and *Zimome*. The former is a brittle, slightly transparent substance, of a yellow colour, and soluble in alcohol; the latter, a hard and tough substance, insoluble in that menstruum. But the existence of these principles is denied by Berzelius.

Yeast.—This substance is always generated during the vinous fermentation of vegetable juices and decoctions, rising to the surface in the form of a frothy, flocculent, somewhat viscid matter, the nature and composition of which are unknown. It is insoluble in water and alcohol, and in a warm atmosphere gradually putrifies; when heated moderately it becomes dry and hard, and may then be preserved without change. Its most remarkable property is that of exciting fermentation.

Vegetable Albumen.—A substance coagulable by heat, and which is very analogous to animal albumen or curd. It was found in the bitter almond by Vogel, in the sweet almond by M. Boullay, and probably exists in most of the emulsive seeds.—*Ann. of Phil.* xii. 39.— *Turner.*

REFERENCES. *Proust on Caseous Oxide and Caseic Acid in Gluten, Brande's Jour.* vii. 389. *Taddei on the Gluten of Wheat, and on Gliadine and Zimome, Ann. of Phil.* xv. 390. *Vogel's analysis of the Cerealia, Ann. of Phil.* xi. 344. *Bostock on the partial solubility of Gluten in water by long digestion, Nicholson's Jour.* xviii. 34. *On the proportion of Gluten in different kinds of Wheat, see Davy's Agricultural Chemistry.* M. *Henry, of Paris, on the same subject, Ann. de Chim. et de Phys.* xl. 223.

SECTION VI.

FERMENTATION.

Under this head may be classed the spontaneous changes to which some vegetable substances are liable, and they may be divided into five distinct kinds, viz., the *panary*, the *saccharine*, the *vinous*, the *acetous*, and the *putrefactive* fermentation.

Panary fermentation.—This name has been applied to the changes which take place in dough during the formation of bread. It has been observed that carbonic acid is the agent in raising the dough; this is evolved by the reaction on the materials, aided by the ferment which is added. It is maintained by Dr. Colquhoun, that all flour contains about five per cent. of sugar,—that the starch and gluten do not necessarily undergo any change in the fermentation of dough,—and that the conversion of sugar into alcohol and carbonic acid, is the essential part of the panary process; and the escape of those volatile products in the oven, leaves the bread full of little cells or vesicles. This view

has been confirmed by Mr. Graham, who obtained from bread, alcohol of sufficient strength to fire gun-powder.—*Colquhoun's Chemical Essay on the art of Baking Bread, Ann. of Phil.* xxviii. 161, 263. *Graham, same work and volume,* 263.

Saccharine fermentation.—The only substance known to be subject to this kind of fermentation is starch.

When gelatinous starch or amidine is kept in a moist state for a considerable length of time, a portion of sugar, about equal to half its weight, is generated. By the access of air the quantity of sugar is increased.

The germination of seeds and the ripening of fruits, have also been regarded by some chemists as examples of that kind of fermentation.

Vinous fermentation.—The conditions necessary to this process are, the presence of sugar, water, yeast or some ferment, and a certain temperature. When one part of sugar is dissolved in five parts of water, and a little yeast added, fermentation quickly takes place if the mixture be exposed to the temperature of about 60° or 70° F. A brisk intestine motion ensues, and the liquor becomes turbid. Some impurities are separated and a frothy scum rises to the surface. A hissing noise is heard, carbonic acid gas is evolved, and the bulk of the liquid is augmented and its temperature is increased. After some time these phenomena cease, the liquor becomes clear, and having lost its sweetness, has acquired a spirituous taste and smell, and is intoxicating. This is *spirit of wine,* and when properly purified, constitutes *alcohol.*

The presence of yeast is not essential to vinous fermentation. The juices of many vegetables contain the saccharine principle essential to this process, together with several other substances which promote it. Thus from the fermented juice of the grape or wine, *brandy* is procured by distillation ; *rum* is procured from the fermented juice of the sugar-cane ; *whiskey* from the fermented decoction of grain ; and *arrack* from fermented rice. The various kinds of ale and beer are produced from a decoction of nutritive grains previously malted ; and they differ from wines, in containing a large quantity of mucilaginous and extractive matter derived from the malt.

Acetous fermentation.—When any of the vinous liquors are exposed to the free access of atmospheric air at a temperature of 80° or 85°, they undergo a second fermentation, terminating in the production of a sour liquid called *vinegar.* During this process a portion of the oxygen of the air is converted into carbonic acid ; hence, unlike vinous fermentation, the contact of the atmosphere is necessary ; and the most obvious phenomenon is, the removal of carbon from the beer or wine [*Brande.*] Vinegar is usually obtained from malt liquor or cider ; but wine is employed in those countries where the grape is abundantly cultivated.

A most important improvement has recently been introduced into the manufactory of vinegar, which it is said is already extensively practiced on the continent of Europe. The introduction of this improvement is chiefly due to Mitscherlich. It is founded on the principle that alcohol, by absorbing oxygen, is changed into acetic acid and water.

This oxidation is promoted by the process of fermentation ; and when the fermentation has begun, is much accelerated by the presence

of acetic acid. The oxidation is effected entirely at the expense of the oxygen of the air ; to accelerate the process, therefore, by producing as many points of contact as possible between the liquid and the air, the following arrangement is adopted. A large cask is taken, placed upright with a stop-cock at the bottom, and a series of holes, half an inch in diameter, bored in each stave, a few inches above it.— It is then nearly filled with chips or shavings of wood, previously steeped in strong vinegar till they are perfectly saturated. Within the upper part of the cask a shallow cylindrical vessel is placed, nearly in contact with the shavings, the bottom of which is perforated with many small holes, each partially stopped with a slender twig which passes an inch or two beneath the perforated bottom of the cylinder. The alcohol diluted with eight or nine parts of water, and mixed with the fermenting substance, is now poured into the cylinder, through the bottom of which it trickles, drop by drop, upon the shavings below, becomes oxidized in its passage, and runs out at the stop-cock beneath, already converted almost entirely into vinegar. The air rushes in by the holes beneath, and passes out above by eight glass tubes, cemented for that purpose into the bottom of the cylinder ; and so rapidly is it deprived of its oxygen, that when it escapes above, it extinguishes a candle. During the process much heat also is developed ; so that from the temperature of 60° F. (that of the room), the interior of the cask rises as high as 86° F. In the proper regulation of this temperature, much of the difficulty consists.

A second transmission of the acid thus obtained, through another similar cask, finishes the process. The whole is concluded in a few hours; four and twenty are considered amply sufficient to convert a given quantity of alcohol into vinegar.—*Johnston's Report.*

Putrefactive fermentation.—Certain vegetable bodies when exposed to air, moisture and to a temperature of from 60° to 100° F., are completely decomposed, or in other words, undergo the process of *putre-faction.* Those proximate principles in which carbon and hydrogen prevail, such as the oils, resins and alcohol, do not putrefy ; nor do the acids which contain a considerable excess of oxygen, suffer this change. Those substances only are disposed to putrefy, in which the oxygen and hydrogen are in proportion to form water ; and even among these a great difference is observable. During this process various gases are evolved ; but its theory is not understood. The chemical action is probably, in some instances, energetic since light is evolved by putrescent wood, and it becomes phosphorescent.

REFERENCES. *For examining the results of Vinous Fermentation, see an apparatus in Lavoisier's Chemistry, and Henry,* ii. 365. *Chaptal's Treatise on the Vine and on Making Wines. Henderson on Wines ; and an article on it in Quarterly Review,* xxxii. 232. *Chaptal on the fermentation of Wine, Repert. of Arts,* 1st ser. xiii. 353. 407. *Dupontal's observations on fermentation from the Ann. de Chim. Repert of Arts,* 2d ser. xix. 239. *Thenard on the same subject, same work.* 2d ser. iv. 67. 130. *Dr. Cooper's Letters on Foreign and Domestic Wines, Emporium of Arts,* iii. *and* iv. *The article Brewing, in the Edinburgh Encyclopedia, and in the Supplement to the Encyclopedia Britannica, the latter by J. Farey. Much interesting and valuable information on Brewing, Distilling, Wine-Making, Baking, &c., will be found in a volume by Mr. Donovan, in Dr. Lardner's Cabinet Cyclopædia, Saussure, Recherches Chimiques sur la Vegetation.*

CHAPTER X.

ANIMAL SUBSTANCES.

All distinct compounds which are derived from the bodies of animals, are denominated *Proximate Animal Principles.* They are distinguished from vegetable matter by the presence of nitrogen, by their strong tendency to putrefy, and the highly offensive products to which their spontaneous decomposition gives rise. But it has already been observed that some vegetable substances likewise contain nitrogen, and again a few of them undergo the putrefactive fermentation. It should also be stated that some compounds of animal origin contain no nitrogen, and are not disposed to putrefy.

The main ingredients of animal matter are carbon, oxygen, hydrogen and nitrogen; in addition to which, other substances are occasionally found in small quantity, as sulphur, phosphorus, iron, and earthy and saline matters.

When heated in close vessels, animal substances yield water, carbonic oxide, carburetted hydrogen, probably free nitrogen and hydrogen, the carbonate and hydrocyanate of ammonia, and a peculiarly fetid thick oil. They may be analyzed or reduced to their ultimate elements in the same manner as vegetable substances.

I shall briefly notice these substances in the following order.

1. Animal acids.
2. Oleaginous substances.
3. Substances which are neither acid nor oleaginous.
4. The more complex animal substances.

SECTION I.

ANIMAL ACIDS.

Several acids are found in animal bodies, which belong equally to the mineral and vegetable kingdoms, and which have been previously described, as the sulphuric, phosphoric, muriatic, carbonic, benzoic, acetic, &c. In this section are included those acids only, which are supposed to be peculiar to animal bodies.

Uric Acid.—Atom. Num. 72—*Symb.* $O + 2N + 6C$.

Discovered by Scheele in 1776. It is a common constituent of urinary and gouty concretions, and is always present in healthy urine, combined with ammonia, or some other base, and in the urine of the *Boa Constrictor,* and other serpents.

PROPERTIES. Pure uric acid is a white powder, which is tasteless and inodorous; it is insoluble in alcohol; very sparingly soluble in cold or hot water, requiring according to Prout, 10,000 times its weight of that fluid at 60° F. for solution; it reddens litmus, and unites with bases, forming salts, which are called *urates* or *lithates*; it undergoes no change by exposure to air; is decomposed by chlorine, but is not acted upon by any acid except the nitric, with which it produces a beautiful purple colour.

PREPARATION. This acid may be obtained from urinary calculus, of which it is one of the most common ingredients, by reducing it to powder in solution of potassa, decomposing the clear solution by excess of muriatic acid, washing the precipitate with a large quantity of distilled water, and drying it at 212° F.

REFERENCES. *Prout's essays on Calculous diseases. Thomson on Uric Acid, First Prin.* ii. 155. *Dr. Henry on the Urates, Manchester Memoirs, N. S.* ii.

Pyro-Uric Acid.—This acid is obtained by subjecting uric acid to heat. It occurs in the form of white acicular crystals; is soluble in boiling alcohol, and in forty times its weight of water; it is not decomposed by digestion in nitric acid. [*Chevallier and Lassaigne, Ann. of Phil.* xvi. 25.] This acid is now supposed to be identical with the cyanuric acid of Leibig and Wohler.

Purpuric Acid.—This was first recognized as a distinct acid by Prout. It occurs in the form of a powder, which is very sparingly soluble in water; does not redden litmus, though it has the power of saturating alkalies; it is insoluble in ether, alcohol and dilute mineral acids, but is readily dissolved by the concentrated ones; its most distinguished character is its tendency to form red or purple salts, called *Purpurates,* though this is denied by Vauquelin.

REFERENCES. *Prout, in Phil. Trans.* 1818. *Lassaigne, Ann. de Chim. et de Phys.* xxii. 334, *who adopts the opinion of Vauquelin that, when pure, this acid does not form purple salts.*

Erythric Acid.—A name applied by Brugnatelli to a substance which he obtained by the action of nitric on uric acid. Prout supposes it to be a super salt, consisting of purpuric and nitric acids, and ammonia. —*Ann of Phil.* xiv. 363.

Rosacic Acid.—A name applied by Proust to a peculiar acid supposed to exist in the red matter, commonly called *lateritious sediment,* which is deposited in some stages of fever. Prout, however, considers it as composed chiefly of purpurate of ammonia.—*Prout on Calculous diseases. Vauquelin and Vogel, Ann. de Chim.* xciv. 306.

Amniotic or Allantoic Acid.—Discovered by Buniva and Vauquelin in the liquor of the amnios of the cow, from which, by slow evaporation, it separates in white crystals. It is very sparingly soluble in water, but yields with the alkalies, compounds which are decomposed by most of the acids.—*Ann. de Chim.* xxxiii. 279. *Thenard, Traité de Chim.* iv. 413.

Lactic Acid.—A name applied to a supposed distinct acid, found in sour milk, &c., but which has been proved to be really the acetic. —*See a memoir on Digestion by Dr. Prout, Ann. of Phil.* xxviii. 407.

Formic Acid.—An acid extracted from ants, which in volatility and odour resembles the acetic, but in composition is entirely different. When sufficiently cooled it becomes solid, but does not crystallize ; its specific gravity is 1 1168; it forms salts with the oxide of copper and other bases which differ from the acetates.—*Ann. of Phil.* v. 24. *Dobereiner has described a process for preparing it artificially, Ann. of Phil.* xx. 311. *See also Thenard,* iv. 415. *Thomson on the atomic weight of Formic Acid, First Prin.* ii. 149.

Caseic Acid.—Discovered in cheese by Proust. It is of the colour and consistence of syrup ; reddens litmus ; has a bitter taste mixed with that of cheese ; it concretes on standing, into a transparent mass like honey, and it precipitates several metallic oxides. Braconnot, however, denies the existence of this acid. [*Ann. de Chim. et de Phys. Oct.* 1827. *Henry,* ii. 278.] Dr. Thomson supposes it to be merely acetic acid, disguised by a quantity of foreign matter, which retards its volatility.—*Inorg. Chem.* ii. 58.

Sebacic Acid.—A name applied by Thenard to an acid which is obtained by the distillation of hog's lard or suet, and is found in the recipient, mixed with acetic acid, and fat partially decomposed. From these it is separated by boiling water and the acetate of lead ; the resulting *Sebate of Lead* is decomposed by sulphuric acid.—*Thenard,* iv. 420.

Cholesteric Acid.—Obtained by Pelletier and Caventou from the biliary concretions, formed in the human subject, by the action of nitric acid. It occurs in the form of an orange-yellow mass ; but when its alcoholic solution is evaporated, spontaneously, it is deposited in acicular crystals of a white colour ; it has a styptic taste, and an odour somewhat like that of butter; it is lighter than water, and fusible at 136° F. ; it reddens litmus and neutralizes alkalies, forming salts called *Cholesterates.*—*Pelletier and Caventou, Jour. de Phar.* iii. 292. *Thenard,* iv. 422.

Stearic Acid.—This acid is always generated by the action of alkalies on the fat of mutton, beef or pork. It is white, insipid and inodorous ; it is insoluble in water, but freely soluble in alcohol ; when heated it reddens litmus ; it combines with bases and forms a class of bodies called *Stearates.*—*Chevreul sur les Corps Gras. Thenard,* iv. 425.

Margaric Acid.—An acid so called by Chevreul from its pearly appearance ; it is insoluble in water, very soluble in alcohol and ether, reddens litmus and unites with bases, forming *Margarates.* It is obtained by putting soap, made of potassa, into water, and decomposing the margarate of potassa, which is deposited, with muriatic acid.—*Chevreul. Thenard,* iv. 430.

Oleic Acid—is thus named by Chevreul in consequence of its oily, colourless appearance ; it has neither taste nor smell ; continues fluid till cooled to 35°, or, in some varieties, to 43° F. ; is insoluble in water, is very soluble in alcohol ; it combines with bases and forms *Oleates.*—*Thenard,* iv. 432.

The two preceeding acids are also formed during the combination of alkalies with the fixed oils.

Phocenic Acid.—A colourless liquid acid, obtained by Chevreul by the action of alkalies upon a peculiar substance contained it the oil of

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the porpoise, *Delphinum Phocœna.*—*Thenard*, iv. 435. It exists also in small quantities in *train oil*, and in the berries of the *Viburnum opulus.*—*Thomson's Inorg. Chem.* ii. 130.

Butyric, Caproic and *Capric Acid.*— These acids are obtained by the action of an alkali upon *Butyrine*, a peculiar oleaginous matter contained in butter.—*Chevreul. Thenard*, iv. 438.

Hircic Acid.—Obtained by the action of an alkali upon the fat of the goat and sheep.—*Chevreul.*

Cetic Acid, is obtained by the digestion of spermaceti with pure potassa.

Other acids more or less analogous to the preceding are formed during the conversion of other oleaginous substances into soap. The castor oil yields three acids, to which MM. Bussy and Lecanu have given the names of *Margaritic, Ricinic* and *Elaiodic Acid.* In a similar way Pelletier and Caventou obtained the *Cevadic Acid* from the oil derived from the seeds of the Veratrum sabadilla and *Jatrophic* or *Crotonic* from the seeds of the croton tiglium.—*Ann. de Chim. et de Phys.* xiv. 71. *Thenard*, iv. 441.

SECTION II.

OLEAGINOUS SUBSTANCES.

Animal oils have many properties in common with those derived from the vegetable kingdom, and are probably essentially the same; but both have some peculiarities. They are extensively employed for giving light, and for the manufacture of soap. Their ultimate elements are carbon, hydrogen and oxygen; and most of them, like the fixed oils, consist of stearine and elaine.

Train Oil.—Obtained by heat from the blubber of the whale, and is extensively employed in making oil gas, and for burning in common lamps; it is of a reddish yellow colour, emits a strong, unpleasant odour, and has a considerable degree of viscidity, which renders it unfit for being burned in Argand's lamps. Even when purified it is far inferior to the spermaceti oil.—*Several processes for depriving this oil of its offensive odour, are described by Mr. Dossie in the Phil. Mag.* xv. *and Chloride of Lime is proposed for the same purpose by Mr. Davidson, Brewster's Ed. Jour.* v.

Spermaceti oil is obtained from an oily matter lodged in a bony cavity in the head of the *Physeter macrocephalus,* or spermaceti whale. On subjecting this substance to pressure in bags, a quantity of pure limpid oil is expressed; and the residue, after being melted, strained, and washed with a weak solution of potassa, is sold under the name of *Spermaceti.*

Spermaceti is an inflammable substance, commonly occurring in crystalline plates, of a white colour and silvery lustre; it is brittle, soft and slightly unctuous to the touch; insoluble in water, but dissolves in about thirteen times its weight of boiling alcohol, and white crystalline plates are deposited as the solution cools, to which Chevreul has given the name of *Cetine.* From this substance a solid colourless

body has been obtained, denominated *ethal*, which resembles ether in its composition.

Animal oil of Dippel.—This name is applied to a limpid volatile oil, which is entirely different from the oils above mentioned, and is a product of the destructive distillation of animal matter, especially of albuminous and gelatinous substances. When purified by distillation, it is clear and transparent. It was formerly much used in medicine, but is now no longer employed.

Hogslard and Suet.—The most common kinds of fat are hogslard and suet, which differ from each other chiefly in consistence. The latter, when separated by fusion from the membrane in which it occurs, is called tallow, which is extensively employed in the manufacture of soap and candles. Both these varieties of fat as well as train and spermaceti oil, consist almost entirely of stearine and elaine ; and when converted into soap undergo the same change as the fixed oils, yielding margaric and oleic acids, and the mild principle of oils called *Glycerine*. Stearic acid is also a constituent of soap made from these animal fats.

Butyrine.—Butter differs from the common animal fats in containing a peculiar oleaginous matter, which is quite fluid at 70° F. and to which M. Chevreul has applied the name of *Butyrine*. When converted into soap, it yields, in addition to the usual products, three volatile odoriferous compounds, namely, the *Butyric, Caproic* and *Capric* acids.

Phocenine is a peculiar fatty substance contained in the oil of the porpoise (*delphinum phocœna*) mixed with elaine. When converted into soap it yields the *Phocenic acid*.

Hircine is contained in the fat of the goat and sheep, and yields the *Hircic acid* when converted into soap.

Adipocire.—A name applied to the fatty matter which remains when a piece of muscle is exposed for some time to the action of water, or is kept in moist earth. According to M. Chevreul, the adipocire is not a pure fatty principle, but a species of soap, chiefly consisting of margaric acid, in combination with ammonia, generated during the decomposition of the fibrin. For some curious facts concerning the formation of adipocire, see *Ure's Chem. Dict.*

Cholesterine.—This name is applied by M. Chevreul to the crystalline matter which constitutes the basis of most of the biliary concretions formed in the human subject. It is a white brittle solid, of a crystalline lamellated structure, and brilliant lustre, very much resembling spermaceti, but it is distinguished from that substance by requiring a temperature of 278° F. for fusion, and by not being convertible into soap when digested in a solution of potassa ; it is free from taste and odour, and is insoluble in water ; it dissolves freely in boiling alcohol, from which it is deposited on cooling in white pearly scales ; when acted on by concentrated nitric acid, it is converted into *Cholesteric acid*. It has been detected in the bile of man, and of several of the lower animals, such as the ox, dog, pig and bear. The best method of preparing it is to treat human biliary secretions, reduced to powder, with boiling alcohol, and to filter the hot solution as rapidly as possible. As the solution cools, most of the cholesterine subsides. —*Chevreul—Thenard,* iv. 506. *Brande's Jour.* xviii. 403.

Ambergris.—A substance found floating on the surface of the sea, near the coasts of India, Africa and Brazil, which is supposed to be a concretion formed in the stomach of the spermaceti whale. It has been commonly regarded as a resinous principle, but its chief constituent is a substance very analogous to cholesterine, and to which Pelletier and Caventou have given the name of *Ambreine.* By digestion in nitric acid, ambreine is converted into a peculiar acid, called the *Ambreic acid.*—*Ann. of Phil.* xvi. 93.

SECTION III.

SUBSTANCES WHICH ARE NEITHER ACID NOR OLEAGINOUS.

Fibrin or Animal Gluten.—This substance forms the basis of the muscular or fleshy parts of animals, and is left, combined with albumen, when all the soluble parts, consisting of gelatine, osmazome, fat, and various salts, have been washed away by hot water. It may be obtained from blood, by laying the coagulum on a linen strainer, and pouring water upon it until a white fibrous matter remains ; or by agitating it in a basin as it flows from a vein, with a bundle of small twigs, which collect it in a stringy form. Fibrin is solid, white, insipid and inodorous ; it is heavier than water, and produces no effect on vegetable colours ; it is soluble in the pure alkalies, but with more difficulty than albumen ; is converted by acetic acid into a tremulous jelly which dissolves completely in warm water ; is variously acted on by the nitric, sulphuric and muriatic acids.

REFERENCES. *For a full history of the properties of Fibrin, see the Memoir of Berzelius, Ann. de Chim.* lxxxviii. 28, *or Medico-Chirurgical Trans.* iii. 201. *For Braconnot's account of Leucine, a substance formed by the action of Sulphuric Acid on Fibrin, see Brande's Jour.* ix. 392. *Thenard, Traité de Chim.* iv. 369.

Albumen.—This enters largely into the composition of both animal fluids and solids. It exists both in the liquid and the solid form. Liquid albumen exists in the serum of the blood, the liquor of serous cavities and the fluid of the dropsy. It is best procured from the white of eggs, in which state it is a thick glairy fluid, insipid, and easily miscible with cold water ; it dries upon being exposed in thin layers to the air, and may then be kept, for any length of time without change ; it is coagulated by heat, alcohol and the stronger acids ; it is precipitated by several of the metallic salts, as muriate of tin, subacetate of lead, and the muriate of gold ; it is distinguished from other animal fluids by its being coagulated by hot water ; its presence may also be detected by corrosive sublimate, and by the ferrocyanate of potassa.—*For further details concerning this substance, see Henry,* ii. 416.

Gelatin, exists abundantly in the skin, cartilages, tendons, membranes and bones, but not in healthy animal fluids. Its distinguishing character is its ready solubility in hot water, and the solution forming a transparent, tremulous jelly, as it cools ; it is insoluble in alcohol, but readily dissolved by most of the diluted acids ; is also dissolved by the liquid alkalies, and the solution is not precipitated by acids.

The gelatin of commerce, commonly known by the name of *Glue*, is prepared by boiling in water the cuttings of parchment, or the skins, ears and hoofs of animals, and evaporating the solution. Isinglass, which is the purest variety of gelatin, is prepared from the sounds of fish, of the genus *Acipenser*, especially from the sturgeon. The animal jelly of the confectioners is made from the feet of calves, the tendinous and ligamentous parts of which yield a large quantity of gelatin.

REFERENCES.   *Thenard, Traité de Chim.* iv.   *Hatchett, on the component parts of Animal Membrane, Phil. Trans.* 1800.   *An account of the methods of making Isinglass, Glue, &c. may be found in Johnson's History of Animal Chemistry,* i. 311.

Urea.—This substance is contained in urine, from which it may be obtained by slowly evaporating the liquid to the consistence of syrup ; on cooling, a crystalline mass is formed, from which pure alcohol dissolves urea. By the careful evaporation of the alcohol, brownish crystals are deposited, which may be purified and rendered colourless. In this state it is soluble in water, especially when hot, and also in alcohol ; it is decomposed by the fixed alkalies and alkaline earths ; though not alkaline it unites with the nitric and oxalic acids, forming sparingly soluble compounds, which crystallize in scales of a pearly lustre, and by which the presence of urea may be detected. This substance has been formed artificially by Wohler.—*Brande's Jour. N. S.* iii. 491.   *Prout's process for preparing Urea, differing somewhat from the above, is described in Henry's and Turner's Chemistry.*

Sugar of Milk.—The saccharine principle of milk is obtained by evaporating that liquid to the consistence of syrup, and allowing it to cool. It is afterwards purified by means of albumen and a second crystallization. It has a sweet taste, though less so than the sugar of the cane, from which also it differs in several other respects.

Sugar of Diabetes.—A kind of sugar which may be obtained in an irregularly crystalline mass, by evaporating the urine voided in the disease called *Diabetes.*

SECTION IV.

THE MORE COMPLEX ANIMAL PRODUCTS.

The Blood and its Constituents.

The blood while circulating in the vessels of living animals, is fluid, of florid red colour in the arteries, and of a dark purple colour in the veins. It has a slightly saline taste, and a peculiar odour, and is somewhat unctuous to the touch ; its specific gravity is variable, though generally near 1·05, and in man its temperature is about 98° or 100° F. ; when fresh drawn it has the appearance of a homogeneous fluid, but if examined with a microscope of sufficient power, numerous red particles are observed floating in a colourless fluid.

The blood, while circulating, is mechanically distinguishable into

two parts, one essentially liquid, which may be called *liquor sanguinis ;* the other essentially solid, which is merely suspended in the former, and imparts its red colour to the mixture. Both of these constituents of the blood are of a complex nature.

Liquor Sanguinis.—This is considered by some as serum, but it has been shown by Dr. B. Babington to be similar to chyle, and to consist of fibrin *held in solution,* along with albuminous, oleaginous and saline matter, by the water of the blood. The *liquor sanguinis* when set at rest coagulates, and forms a uniform jelly of precisely the same volume as when it was liquid, and possesses the exact figure of the containing vessel; and in a short time, by the contraction of the mass of coagulated fibrin a yellowish liquid appears, which is the true *serum* of the blood.

It is the liquor sanguinis, thus shown to be spontaneously separable into fibrin and serum, which forms a yellowish liquid stratum at the surface of blood recently drawn from persons in acute rheumatism or other inflammatory fevers. In such affections the liquor sanguinis, from causes not at all understood, generally coagulates with unusual slowness, so that the heavier red globules have time to subside to an appreciable extent, leaving an upper stratum of nearly colourless fluid, which by the cautious use of a spoon may be removed and collected into a separate vessel. The *buffy coat* of such blood is pure fibrin separated by coagulation from the liquor sanguinis. The *coagulable lymph* of Surgeons, which is thrown out on cut surfaces, appears to be the liquor sanguinis ; and this fluid is also not unfrequently exhaled in dropsies, when the fibrin either constitutes a gelatinous deposit, or appears as white flakes floating in a serous fluid. It is poured out by the intestines during an attack of cholera, the rice-water fluid characteristic of that disease, consisting of a saline and albuminous solution, in which numerous shreds of fibrin are suspended.— *Turner.*

By allowing blood to remain exposed for a short time to the air, it separates spontaneously into two distinct portions :—a yellowish liquid called *serum,* and which is identical with that obtained from the liquor sanguinis ; and a red solid known by the name of *clot, cruor* or *crassamentum.* The relative proportion of these two parts is variable, and depends upon circumstances not at all connected with the state of vigour and health of the animal from which the blood is drawn.

Serum.—This liquid has a yellowish colour, a saline taste and slightly alkaline reaction ; it is somewhat unctious to the touch, and resembles in fluidity warm olive oil; its specific gravity is from 1·027 to 1·029; it is coagulated by heat, and by acids, alcohol and other substances that coagulate albumen. When the coagulum prepared by heat, is cut into thin slices and subjected to pressure, it yields a small quantity of a colourless, limpid fluid, called *serosity*—which contains according to Dr. Bostock, about 1-50th its weight of animal matter, together with a little muriate of soda.

The serum of human blood, according to Berzelius, consists in 100 parts of water 90·59, albumen 8, lactate of soda with animal matter and chloride of sodium 1, modified albumen and an alkaline phosphate and carbonate 0·41.— *Traité de Chim.* vii. 75.

Crassamentum or Clot.—This is the firm coagulating portion of the blood, and has the specific gravity of about 1·245. It may be resolved into two portions by cutting it into thin slices and washing it repeat-

edly in distilled water ; the colouring matter, called the *red globules*, is gradually dissolved or washed out, and a white fibrous substance remains called *fibrin*.

Colouring matter of the blood.—To this substance the name of *hematosine* is now applied. It resembles albumen in most of its properties, except in colour. Its elementary composition is nearly similar to that of fibrin and albumen, but it differs from both, in containing iron. This has been satisfactorily shown by Berzelius, Engelhart and Rose.

From the presence of iron in the colouring matter of the blood, some were led to suppose that the peculiar colour of the blood was in some way or other dependent upon that substance. But this view, although supported by many plausible arguments, does not seem to be warranted by the facts. Nor can we at present adopt the opinion of Mr. Brande, that the colouring matter is a peculiar animal principle, capable of combining with metallic oxides.

With regard to the colour of the blood, a very interesting fact has been stated by Dr. Stevens in his Treatise on the blood, and confirmed by Dr. Turner and others who have repeated the experiment. If perfectly florid arterial blood be allowed to coagulate, and the clot be washed with repeated portions of pure water, its colour gradually darkens so as at last to appear quite black. Exposure to the air does not restore the colour, but a solution of common salt, carbonate of soda, and other neutral salts restore it to the original colour of arterial blood. Dr. Stevens has therefore drawn the conclusion, that the florid colour of arterial blood is not due to oxygen, but to the saline matter of the serum.

Analysis of the Blood.—A very elaborate examination of the blood has been recently made by Lecanu. The following is the mean of the results of two analyses.

Water	782·867
Colouring matter	126·313
Albumen	67·252
Fibrin	2·832
Saline, oily, fatty, and extractive matter	20·736
	1000·000

Lecanu has observed a difference between the relative proportions of the ingredients of the blood in men and women ; and this observation has been confirmed by Dennis, who has made a more extended examination on this subject.—*Ann. de Chim.* xlviii. 308. *Jour. de Pharm.* xvii. 522, *quoted in Johnston's Report.*

- REFERENCES. *Bostock in Medico-Chirurgical Trans.* ii. 166. iii. 231 ; *and also his work on Physiology. Brande, in Phil. Trans.* 1812, *and his Manual of Chemistry. Engelhart, in Edin. Med. and Surg. Jour.* Jan. 1827. *Scudamore on the Blood. Dr. J. Davy's Observations on the Fibrin, Buffy Coat, and presence of Carbonic Acid in the Blood, and on the Heat given off during the coagulation of the Blood, &c. in Edin. Med. and Surg. Jour.* xxix. 244, xxx. 248, xxxi. 21. *Berzelius on the presence of Iron in the Blood, Ann. de Chim. et de Phys.* v. 42, *and Traité de Chim.* vii. 60.

Respiration.—This function consists of two distinct actions, that of *inspiration*, by which the air is drawn into the lungs ; and that of *ex-*

piration, by which it is expelled after having served the purpose for which it is inhaled. By an easy natural inspiration, from 16 to 20 cubic inches may perhaps, on an average, be the quantity taken in by man of middle size. By a forced expiration, from 160 to 170 cubic inches may be expelled, after which there still remain in the lungs about 120 cubic inches, making their entire contents about 290 cubic inches. Calculating from the number of inspirations in 24 hours, and the quantity inspired at each, it would appear that about 666 cubic feet of air are breathed during every diurnal period.—*Henry*, ii. 460.

The air exhaled from the lungs is charged with carbonic acid. This can be rendered manifest by breathing into lime-water, which becomes turbid in consequence of the formation of carbonate of lime.

But with regard to the amount of this gaseous acid which is formed, some difference of opinion exists. It was formerly supposed that it was exactly equal to the amount of oxygen consumed, but more recent researches, and especially those of Dulong and Despretz, concur in fixing the amount of oxygen consumed as greater than that of the carbonic acid formed, varying in different animals from 1-10th to one half.

According to Drs. Prout and Fyfe, the quantity of carbonic acid formed in the lungs is liable to be materially affected in its quantity, in the same individual, by various circumstances. These variations they consider of two kinds, general or diurnal, and particular.

It has been generally supposed that the bulk of nitrogen inhaled during respiration is not changed, and that this gas is merely passive in the process, or at least that its only use is to neutralize the energetic properties of the oxygen. But it has been shown by that acute physiologist, Dr. Edwards, that the quantity of nitrogen given out by the same animal, during respiration, is very variable, being at one time increased, at another diminished, and at a third remaining wholly unchanged. These phenomena he has traced to the influence of the seasons. It has also been shown by Allen and Pepys, that when animals are confined in vessels of oxygen gas, or in an atmosphere composed of 21 measures of oxygen and 79 of hydrogen, the residual air contains a large quantity of nitrogen, and in the latter case a portion of the hydrogen has disappeared. Dulong and Despretz also, in their experiments, arrived at the conclusion that in all cases there was an increase of nitrogen.

It appears therefore little doubtful, that nitrogen is constantly given out by the lungs.

From the experiments of Dr. Edwards it appears to be proved, that carbonic acid given out by the lungs, is formed in the blood during its circulation. For on confining animals for some time in an atmosphere of hydrogen, the residual air was found to contain a quantity of carbonic acid, which was in some instances greater than the bulk of the animal. It may also be inferred from these and other experiments, that nitrogen is absorbed during respiration. And I have elsewhere made the suggestion, that the nitrogen thus absorbed combines with carbon and forms cyanogen, which probably exists in the blood in combination with iron.—*For the facts and arguments in favour of this view, see Sill. Jour.* xviii. 52, *and N. Y. Med. and Phys. Jour.* ix. 288.

REFERENCES. *Bostock's Physiology. Edwards De l'Influence des Agents Physiques sur la Vie. Prout on the Phenomena of Sanguification,*

and on the blood in general, Ann. de Phil. xiii. 12, 265. *The experiments of Allen and Pepys, Phil. Trans.* 1808. *Christison's Inquiry on some disputed points in the chemical physiology of the Blood and Respiration, Edin. Med. and Surg Jour.* xxxv. 94. *For a good summary of the various opinions, &c. see Henry's Chem.* ii. *For a full account of the former theories and views on this and various other subjects relating to this department, consult Johnson's History of Animal Chemistry, in three vols. Lond.* 1803.

Animal Heat.—The production of animal heat appears to be closely connected with respiration. A portion of it, at least, can be satisfactorily accounted for by the formation of carbonic acid. The remainder has been ascribed to various other sources, as the processes of nutrition, secretion, &c. Mr. Brodie, however, refers animal heat altogether to the influence of the nervous system. But his results have not been confirmed by other physiologists. There is therefore much obscurity resting upon this subject.

REFERENCES. *Crawford on Animal Heat. Ellis' Inquiry. ˮ Dr. J. Davy, Phil. Trans. for* 1814. *The author controverts the opinion of Crawford as to the difference in the capacities of venous and arterial Blood. Brodie, in Phil. Trans.* 1811 *and* 1812. *He ascribes animal Heat wholly to nervous influence.*

Animal Fluids, Secretions, &c.

Saliva.—The saliva is the fluid secreted by the salivary glands, and is poured into the mouth during mastication. It is a transparent, colourless and slightly viscid fluid, consisting of albumen and several saline substances dissolved in water. From the recent analysis of Tiedemann and Gmelin, the chief saline constituent is muriate of potassa ; but several other salts, such as the sulphate, phosphate, acetate, carbonate, and sulphocyanate of potassa, are likewise present in small quantity. The concretions found in the salivary glands consist chiefly of carbonate of lime.

REFERENCE. *Bostock's Physiology, containing the experiments of Tiedemann and Gmelin.*

Pancreatic Juice.—This fluid is commonly supposed to be analogous to the saliva, but it appears from the analysis of Tiedemann and Gmelin, that it is essentially different. The chief animal matters are albumen, and a substance like curd ; but it also contains a small quantity of salivary matter and osmazome. It reddens litmus paper, owing to the presence of free acid, which is supposed to be the acetic. Its salts are nearly the same as those contained in the saliva, except that the sulphocyanic acid is wanting. The uses of this fluid are entirely unknown.

Gastric Juice.—This is a fluid poured out on the mucous coat of the stomach, and appears to be possessed of extraordinary powers as a solvent. As collected from the stomach of an animal killed while fasting, it is a transparent fluid, which has a saline taste, and has neither acid nor alkaline reaction ; during the process of digestion however, it appears to be distinctly acid ; it coagulates milk, an effect which is

supposed to be independent of the presence of an acid. Its powers cannot be explained upon any known chemical principles.

REFERENCES. *Prout, in Phil. Trans.* 1824. *Bostock's Physiology.*

Bile.—The bile is a yellow or greenish-yellow coloured fluid, of a peculiar sickening odour, and of a taste at first sweet and then bitter, but exceedingly nauseous. Its consistence is variable, being sometimes limpid, but more commonly viscid and ropy ; it is rather denser than water, and may be mixed with that liquid in every proportion, it contains a minute quantity of free soda, and is, therefore, slightly alkaline ; but owing to the colour of the bile itself, its action on test paper is scarcely visible.

The bile, according to the analysis of Tiedemann and Gmelin, is a very complex fluid, containing, besides many other ingredients, a peculiar acid, called the *Cholic,* which crystallizes in needles, reddens litmus paper, and has a sweet taste.

The peculiar taste of the bile is owing to a substance first obtained, but not in a pure state, by Thenard, and called by him *Picromel.*

This substance, when pure, occurs, according to the above named chemists, in opake crystalline grains ; soluble in water and in alcohol, but not in ether ; its taste is sweet without any bitterness.

REFERENCES. *Thenard, in Memoirs d'Arcueil,* i. *or Traité de Chim.* iv. 398. *Berzelius, who denies the presence of Picromel in the Bile, Ann. de Chim.* lxxi. 220.

Biliary Calculi.—The concretions sometimes found in the human gall-bladder, consist, according to M. Chevreul, in general of the yellow colouring matter of the bile and cholesterine ; the latter predominating and being sometimes in a state of purity.

Chyle.—The fluid absorbed by the lacteal vessels from the small intestines during the process of digestion, is known by the name of *Chyle.* Its appearance varies in different animals ; but as collected from the thoracic duct of a mammiferous animal, three or four hours after a meal, it is a white opake fluid like milk, having a sweetish and slightly saline taste. In a few minutes after removal from the duct, it becomes solid, and in the course of twenty-four hours separates into a firm coagulum, and a limpid liquid, which may be called the serum of the chyle. The coagulum is an opake white substance, of a slightly pink hue, insoluble in water, but soluble easily in the alkalies and alkaline carbonates. Vauquelin regards it as fibrin in an imperfect state, or as intermediate between that principle and albumen ; but Mr. Brande considers it more closely allied to the caseous matter of milk than to fibrin.

Milk.—This well known fluid, secreted by the females of the class *mammalia* for the nourishment of their young, consists of three distinct parts, the cream, curd, and whey, into which by repose it spontaneously separates. The cream, which collects upon its surface, is an unctious, yellowish-white, opake fluid, of an agreeable flavour.—According to Berzelius, 100 parts of cream of specific gravity 1·0244, consist of butter 4·5, caseous matter 3·5, and whey 92. By agitation as in the process of churning, the butter assumes the solid form, and is thus obtained in a separate state. During the operation there is an

increase of temperature amounting to about three or four degrees, oxygen gas is absorbed, and an acid is generated; but the absorption of oxygen cannot be an essential part of the process, since butter may be obtained by churning, even when atmospheric air is entirely excluded.

After the cream has separated spontaneously, the milk soon becomes sour, and gradually separates into a solid coagulum, called curd, and a limpid fluid which is whey. This coagulation is occasioned by free acetic acid, and it may be produced at pleasure either by adding a free acid, or by means of the fluid known by the name of *rennet*, which is made by infusing the inner coat of a calf's stomach in hot water. When an acid is employed, the curd is found to contain some of it in combination, and may, therefore, be regarded as an insoluble compound of an acid with the caseous matter of milk; but nothing certain is known respecting the mode by which the gastric fluid, the active principle of rennet, produces its effect.

The curd of skim-milk, made by means of rennet, and separated from the whey by washing with water, is *caseous matter*, or the basis of cheese, in a state of purity. It is a white, insipid, inodorous substance, insoluble in water, but readily soluble in the alkalies, especially in ammonia. By alcohol it is converted, like albumen and fibrin, into an adipocirous substance, of a fetid odour; and, like the same substance, it may be dissolved by a sufficient quantity of acetic acid.

REFERENCES. *Braconnot, Edin. Jour. of Science*, viii. 369, *denies the accuracy of Proust's observations concening Caseous Oxide and Caseic Acid.*

Eggs.—The shell of eggs is composed principally of carbonate of lime with a little animal matter. The white consists of albumen; the yolk consists principally of a substance resembling albumen and a semi-fluid oil, which may be separated from the other portions by boiling the egg. The yolk contains a large quantity of phosphorus, which is obviously to supply phosphoric acid for forming the bones of the chick.

REFERENCE. *Prout, Phil. Trans.* 1822.

Humours of the Eye.—The aqueous and vitreous humours of the eye, are composed principally of water, with some saline matter, and a trace of albumen. The crystalline lens contains more than half its weight of water and the remainder is a peculiar animal matter, very analogous to albumen, with a trace of salts.

REFERENCE. *Bostock's Physiology.*

Tears.—The tears are limpid and of a saline taste, dissolve freely in water, and owing to the presence of free soda, communicate a green tint to the blue infusion of violets. Their chief salts are the muriate and phosphate of soda. According to Fourcroy and Vauquelin, the animal matter of the tears is mucus; but it is more probably either albumen, or some analogous principle. Its precise nature has not however been satisfactorily determined.

Mucus.—This term appears to have been used in very different significations. Its properties vary somewhat, according to the source from which it is derived; but its leading characters are in all cases the same, and are best exemplified in the mucus from the nostrils. It appears to have nearly the same composition as tears, but being more exposed to the air, it suffers with more rapidity those changes caused by the absorption of oxygen, and hence its greater viscidness and consistence.

REFERENCE. *On the different kinds of Mucus, see Thenard,* iv. 592.

Pus.—This is the fluid secreted by an inflamed and ulcerated surface. Its properties vary according to the nature of the sore from which it is discharged. Healthy pus is a yellowish-white coloured liquid, of the consistence of cream, and of a peculiar odour when warm; under the microscope it appears to be composed of solid globules, floating in a transparent fluid; its specific gravity is about 1·03: it is insoluble in water, and is thickened, but not dissolved by alcohol; it produces no change on vegetable blues, and is dissolved by the stronger acids. It is distinguished from mucus according to Grassmeyer, as follows: triturate it with its own weight of water, then mix it with an equal quantity of a saturated solution of the carbonate of potassa. If it contain pus, a transparent jelly forms in a few hours; but this does not happen if mucus only is present.

REFERENCES. *For Grassmeyer's test, see Thomson's Syst.* iv. *Dr. Young on Consumptive Diseases, gives a test for distinguishing Pus from Mucus, founded on optical properties. Sir E. Home on Ulcers.*

Sweat.—The excretion which is continually passing off by the skin in the form of insensible perspiration, consists chiefly of water; but it contains some muriate of soda and free acetic acid, in consequence of which it has a saline taste and an acid reaction.

Urine.—Urine is an excretory fluid separated from the blood by the kidneys. In its natural healthy state, it is a transparent, limpid fluid, of an amber colour, having a saline taste, while warm emitting an odour which is slightly aromatic, and not at all disagreeable. Its specific gravity in its most concentrated form, is about 1·030. It gives a red tint to litmus paper, a circumstance which indicates the presence either of a free acid or of a super-salt. Though at first quite transparent, an insoluble matter is deposited on standing; so that urine, voided at night, is found to have a light cloud floating in it by the following morning. This substance consists in part of mucus from the urinary passages, and partly of the superurate of ammonia, which is much more soluble in warm than in cold water.

The urine is very prone to spontaneous decomposition. When kept for two or three days, it acquires a strong urinous smell; and as the putrefaction proceeds, the disagreeable odour increases, until at length it becomes exceedingly offensive. As soon as these changes commence, the urine ceases to have an acid reaction, and the earthy phosphates are deposited. In a short time, a free alkali makes its appearance, and a large quantity of carbonate of ammonia is gradually generated. Similar changes may be produced in recent urine by continued boiling. In both cases the phenomena are owing to the decompo-

sition of urea, which is almost entirely resolved into carbonate of ammonia.

According to the researches of Berzelius, the urine is one of the most complex animal fluids, consisting of more than twenty different substances. Of these, water constitutes 933 parts in 1000 of urine.

The composition of the urine, however, is much changed by the influence of certain diseases: thus, sugar is found in the urine voided in diabetes; in some cases of jaundice it is tinged of a yellow colour by the bile; and in certain kinds of dropsy, albumen is present in it in large proportion.

REFERENCES. *For the able researches of Berzelius on Urine, &c. see his general views of the composition of Animal Fuids, in Ann. of Phil. ii. 19, 195, 377, 415, and his Animal Chemistry. Proust, Ann. de Chim. xxxvi. 258. John, on the absence of Urea in Hepatitis, Ann. of Phil. v. 424, vi. 392.—Prout on the pink sediment from Urine, Medico Chir. Trans. ix. 481. Ann. of Phil. xv. and xvi.*

Urinary Concretions.—The most common kind of urinary concretions may be conveniently divided into the following species: 1. The uric acid calculus; 2. The bone-earth calculus, principally consisting of phosphate of lime; 3. The ammoniaco-magnesian phosphate; 4. The fusible calculus, being a mixture of the two preceding species; 5. The mulberry calculus, composed of oxalate of lime: 6. The cystic oxide calculus; 7. The alternating calculus; and, 8. The compound calculus.

The *Uric Acid Calculus*, is a hard inodorous concretion, commonly of an oval form, of a brownish or fawn colour, and smooth surface; it consists of layers arranged concentrically around a central nucleus, the laminæ being distinguished from each other by a slight difference in colour; it is sparingly soluble in water, and muriatic acid; is soluble with effervesence, by nitric acid, and the solution yields purpurate of ammonia when evaporated; when digested in pure potassa the acid is dissolved and the other substances remain; before the blow-pipe it becomes black, emits a peculiar animal odour, and is gradually consumed, leaving a very small quantity of white alkaline ashes.

The *Bone-earth Calculus*, is of a pale brown colour, and has a very smooth surface; it consists of layers, which adhere so slightly that they may be separated with ease into concentric crusts; in powder, it dissolves easily in dilute nitric or muriatic acid, but is insoluble in potassa; before the blow-pipe it first assumes a black colour, from the decomposition of a little animal matter, and then becomes quite white, undergoing no further changes unless the heat be very intense, when it is fused.

The *Triple Phosphate Calculus* rarely exists quite alone, but is generally associated with a small proportion of phosphate of lime. It often occurs in minute crystals diffused over the surface, or between the interstices of other calculus laminæ; is generally white and less compact than the preceding; when reduced to powder it is easily dissolved by cold acetic acid, and still more easily by the stronger acids, the salt being thrown down unchanged by ammonia; before the blow-pipe a smell of ammonia is given out, it diminishes in size, and melts into white pearl with rather more facility than phosphate of lime.

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The *Fusible Calculus* is recognized by the property from which it derives its name. Before the blow-pipe it froths and runs into a globule, which is either perfectly transparent or of a pearly whiteness; it consists of a mixture of the phosphate of lime and triple phosphate of ammonia and magnesia.

The *Mulberry Calculus* is named from its resemblance in its rough tuberculated surface, to the fruit of the mulberry. It consists of oxalate of lime, as was first proved by Dr. Wollaston; when heated before the blow-pipe it becomes black, and afterwards white, and on continuing the heat, a white residuum of pure lime is obtained, which gives a brown stain to moistened tumeric paper. This calculus is sometimes smooth, and when mixed with uric acid becomes more refractory, and decrepitates before the blow-pipe.

The *Cystic Oxide Calculus*, is very rare. It resembles the triple phosphate calculus, but is more compact; before the blow-pipe it emits a peculiarly fœtid smell; it is readily soluble in almost all acids, and in the alkalies; is insoluble in alcohol, water, acetic, tartaric or citric acids, or in solutions of neutral carbonate of ammonia; it is composed of animal matter, and it is never accompanied with the matter of any other concretion.

The *Alternating Calculus*, is composed of alternate layers of two or more of the substances already mentioned, as constituting calculi; a fragment of each of the layers may be broken off, and its nature determined by the application of the blow-pipe, and other tests above mentioned.

The *Compound Calculus*, may be known from the equivocal results presented when it is subjected to chemical examination; it is composed of an intimate mixture of the ingredients of other calculi.

Besides the calculi just mentioned, three other species have been noticed. Two of these were described by Dr. Marcet, under the names of *Xanthic Oxide* and *Fibrinous Calculus*, both of which are exceedingly rare. The former is of a reddish or yellow colour, is soluble in acids and in alkalies, and its solution in nitric acid, when evaporated, assumes a bright lemon-yellow tint; the latter derives its name from fibrin, to which its properties are closely analogous. The third species consists chiefly of carbonate of lime, and is likewise of rare occurrence.

REFERENCES. *Marcet's Essay on the chemical history and medical treatment of Calculous disorders. The papers of Dr. Wollaston and Prof. Brande, in Phil. Trans.* 1797 *and* 1810. *Proust's inquiry into the nature and treatment of Gravel, Calculus, &c. Dr. Yelloly, in Phil. Trans.* 1829. *Dr. Henry on Urinary and other Morbid Concretions, Ann. of Phil.* xv. 107. *See also the works of Thomson and Thenard.*

Solid Parts of Animals.

Bones.—These consist of earthy salts and animal matter intimately blended, the former of which are designed for giving solidity and hardness, and the latter, for agglutinating the earthy particles. The animal substances are chiefly cartilage, gelatin, and a peculiarly fatty matter called marrow.

According to the analysis of Berzelius, 100 parts of dry human bones consist of animal matters 33·3, phosphate of lime 51·04, carbonate

of lime 11·30, fluate of lime 2, phosphate of magnesia 1·16, and soda, muriate of soda, and water 1·2. Mr. Hatchett found, also, a small quantity of the sulphate of lime; and Fourcroy and Vauquelin discovered traces of alumina, silica, and the oxides of iron and manganese.

REFERENCES. *Processes for extracting Gelatine from Bones, by D'Arcet, and Gauthier, Repert. Arts. 2d Ser.* xlv. 50. *Repert. of Pat. Invent* vi. 321. *On the use of the Gelatine of Bones procured from Butchers' Meat, as on Alimentary Substance, by M. D'Arcet, Repert. of Pat. Invent. &c.* xi. 25.

Teeth are composed of the same materials as bone; but the *enamel* dissolves completely in dilute nitric acid, and therefore is free from cartilage. The composition of *Ivory* is similar to that of the bony matter of teeth in general.

The *Shells of Eggs* and the covering of crustaceous animals, such as lobsters, crabs, and the starfish, consist of the carbonate and a little phosphate of lime, and animal matter. The shells of oysters, muscles, and other molluscous animals consist almost entirely of carbonate of lime, and animal matter, and the composition of *Pearl and Mother of Pearl* is similar.

Horn differs from bone in containing only a trace of earth. It consists chiefly of gelatin and a cartilaginous substance like coagulated albumen. The composition of the *nails* and *hoofs* of animals is similar to that of horn; and the cuticle belongs to the same class of substances.

Tendons appear to be composed almost entirely of gelatin; for they are soluble in boiling water, and the solution yields an abundant jelly on cooling. The composition of the true skin is nearly the same as that of tendons. Membranes and ligaments are composed chiefly of gelatin, but they also contain some substance which is insoluble in water, and is similar to coagulated albumen.

In *Hair*, Vauquelin found traces of silex, sulphur, iron and manganese and a peculiar oil, which is nearly colourless in white hair, blackish-green in dark hair, and red in red hair.

The composition of *Wool* and *Feathers* appears analogous to that of hair. The quill part of the feather was found by Mr. Hatchett to consist of coagulated albumen.

The flesh of animals, or *Muscle*, consists essentially of fibrin, but independently of this principle, it contains several other ingredients, such as albumen, gelatin, a peculiar extractive matter called *Osmazome*, fat and salts; substances which are chiefly derived from the blood, vessels, and cellular membrane, dispersed through the muscles.

APPENDIX.

CONTAINING EXPLANATIONS OF CHEMICAL TERMS, DESCRIPTIONS OF APPARATUS, TABLES OF ATOMIC WEIGHTS, OF SPECIFIC GRAVITIES, OF WEIGHTS AND MEASURES, &c. &c., ALPHABETICALLY ARRANGED.

ACIDS. A term originally applied to those bodies only which have a sour taste; but recently the name has been extended to other substances. All those substances are now called acids which unite with alkalies and metallic oxides to form salts.

ADOPTER. The tube represented in the accompanying figure is known by this name. It is sometimes used in the distillation of acids, and is connected to the retort and the receiver by luting.
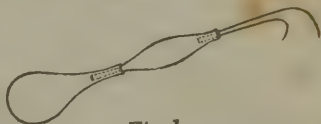
Fig. 1.

AIR. In a general sense this term is applied to any permanently elastic fluid which is so similar, in this, and other qualities, to common air, as to be classified under the same general name. It is also often applied to *Atmospheric Air*, to distinguish it from the other gases.

AIR, *Pressure of*, a term sometimes used in place of the weight or the pressure of the atmosphere.

ALCHEMY. The name of a visionary pursuit which, for many centuries, was directed to the discovery of the philosopher's stone, and the universal elixir; by the former of which the baser metals were to be transmuted into the precious metals, and by the latter, human life was to be indefinitely prolonged.

ALEMBIC. A vessel of glass or of metal, sometimes employed for distilling liquids or for subliming volatile substances. It consists of two parts; the materials to be sublimed or distilled are put into the lower part, and the upper part is ground to it or joined with a proper cement. The small tube proceeding from the lower part of the capital carries off any watery vapour that may be condensed, which would otherwise drop into the lower part and break it. When the alembic is used for the sublimation of benzoic acid, or of any other substance where only a very gentle heat is required, the heat may be applied in the usual way by a chaufer, supporting it by a retort-stand. When a higher temperature is necessary, it may be placed in a sand bath.

Fig. 2.

ALKALIES. Substances that have an acrid taste, change blue vegetable colours to green, and form salts by their union with acids.

ALKALIMETER. An instrument for ascertaining the quantity of real alkali in different samples of commercial potash and pearlash. A convenient mode of effecting this object is described by Mr. Faraday in his work on chemical manipulation. Into a tube sealed at one end, 9½ inches long, ⅜ths of an inch in diameter, and as cylindrical as possible in its whole length, pour 1000 grains of water, and with a file or diamond mark the place where its surface reaches, and divide the space occupied by the water into 100 equal parts, as is shown in the figure. Opposite to the numbers 23.44, 48.96, 54.63, and 65, draw a line, and at the first write soda, at the second potassa, at the third carbonate of soda, and at the fourth carbonate of potassa. Then prepare a dilute acid having the specific gravity of 1.127 at 60°, which may be made by mixing one measure of concentrated sulphuric acid with four measures of distilled water. This is the standard acid to be used in all the experiments, being of such strength that when poured into the tube till it reaches either of the four marks just mentioned, we shall obtain the exact quantity which is necessary for neutralizing 100 grains of the alkali written opposite to it. If when the acid reaches the word *Carb. Potassa*, and when consequently, we have the exact quantity

Fig. 3.
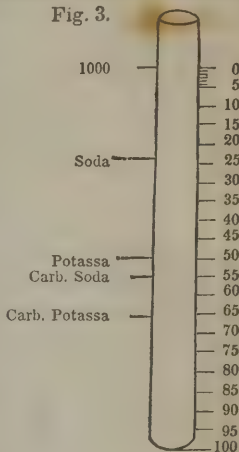
which will neutralize 100 grains of that carbonate, pure water be added until it reaches 0, or the beginning of the scale, each division of this mixture will neutralize one grain of carbonate of potassa. All that is now required, in order to ascertain the quantity of real carbonate in any specimen of pearlash, is to dissolve 100 grains of the sample in warm water, filter to remove all the insoluble parts, and add the dilute acid in successive small quantities, until by the test of litmus paper, the solution is exactly neutralized. Each division of the mixture indicates a grain of pure carbonate. It is convenient, in conducting this process, to set aside a portion of the alkaline liquid, in order to neutralize the acid, in case it should at first be added too freely.

It is obvious that upon a similar principle we can ascertain the quantity of real acid in any given amount of diluted acid, and the instrument then becomes an *acidimeter*.

ALLOY. A term applied to the compounds of two or more metals. Thus brass is called an alloy of copper and zinc.

AMALGAM. This name is applied to the combinations of mercury with the other metals. Thus a compound of mercury and tin is called an amalgam of tin.

ANALYSIS. The separation of a compound body into the component parts of which it consists.

37*

ANHYDROUS. Destitute of water.

ANNEALING. When applied to metals, it is an operation which consists in making them red hot, and then letting them cool gradually, in order to restore their malleability, which they are apt to lose under the operation of hammering. The *annealing of glass* is conducted in the same manner, and is necessary to its perfection, for otherwise it would be apt to fly into pieces by the slightest scratch, or upon changes of temperature.

Fig. 4.

APHLOGISTIC LAMP. One which burns without flame. It may be made by attaching a coil of platinum wire to the wick of a small alcohol lamp, and then setting fire to the wick so as to heat the platinum wire. If now the flame be blown out, the wire continues to glow until all the alcohol in the lamp is consumed.

AQUA REGIA. An acid compounded of nitric and muriatic acids, used to dissolve gold and platinum. Gold was formerly called the king of the metals, and hence the above name was given to this acid. It is now usually called nitro-muriatic acid. See page 142.

AQUEOUS VAPOUR, (Latin *aqua*, water) is the vapour of water. See *Vapour*.

Fig. 5.

AREOMETER. An instrument for determining the specific gravity of liquids. Its use depends upon the principle that a body sinks deeper in a lighter than in a heavier liquid. The areometer of Baumé is in most common use. It is constructed upon the same principle as the common hydrometer, although the graduation is different. It is of two kinds; one for liquids lighter than water, and the other for liquids heavier than water.

ASSAY. An operation employed to determine the quantity of precious metal contained in any mineral mixture by analyzing a small part thereof.

ATOM. A term derived from the Greek *a* privative, and *tamno,* I cut, and employed to designate the simplest particles in nature—what are incapable of further division. Every body is supposed to consist of an assemblage of such minute particles or atoms. See page 32.

TABLE *of the Atomic Weights and Symbols of the Elementary, and most important Compound, Bodies.— The atomic weights are referred to Hydrogen as* 1.

Names of Substances.	Symbols.	Atom. Wts.	Names of Substances.	Symbols.	Atom. Wts.
ALUMINUM	Al	13.7	CERIUM	Ce	46
oxide,(alumina)	Al+1½O	25.7	oxide,	Ce+O	54
chloride,	Al+Cl	49.15	peroxide,	Ce+1½O	58
ANTIMONY	Sb	64.6	CHLORINE	Cl	35.45
oxide,	Sb+1½O	76.6	protoxide,	Cl+O	43.45
deutoxide,	Sb+2)	80.6	peroxide,	Cl+4O	67.45
peroxide,	Sb+2½O	84.6	chloric acid,	Cl+5O	75.45
sesquichloride,	Sb+1½Cl	117.7	perchloric acid,	Cl+7O	91.45
perchloride,	Sb+2½Cl	153 22	CHROMIUM	Cr	28
sesquisulphuret,	Sb+1½S	88.6	oxide,	Cr+1½O	40
bisulphuret,	Sb+2S	96.6	chromic acid,	Cr+3O	52
ARSENIC	As	37.7	chloride,	Cr+1½Cl	81.22
arsenious acid,	As+1½O	49.7	terchloride,	Cr+3Cl	134.35
arsenic acid,	As+2½O	57.7	terfluoride,	Cr+3F	84.04
sulphuret,	As+S	53.7	COBALT.	Co	29.5
sesquisulphuret,	As+1½S	61.7	oxide,	Co+O	37.5
persulphuret,	As+2½S	77.7	peroxide,	Co+1½O	41.5
BARIUM	Ba	68.7	chloride,	Co+Cl	64.95
protoxide (bary-			sulphuret,	Co+S	45.5
ta)	Ba+O	76.7	COLUMBIUM.	Cb	185
peroxide,	Ba+2O	84.7	oxide,	Cb+2O	201
chloride,	Ba+Cl	104.15	columbic acid,	Cb+3O	209
sulphuret, .	Ba+S	87	COPPER	Cu	31.6
BISMUTH	Bi	71	suboxide, (red)	2Cu+O	71.2
oxide,	Bi+O	79	protoxide(black)	Cu+O	39.6
chloride,	Bi+Cl	106.45	superoxide,	Cu+2O	47.6
sulphuret,	Bi+S	87	subchloride,	2Cu+Cl	98.65
BORON	B	8	chloride,	Cu+Cl	67.05
BROMINE.	Br	78.26	disulphuret,	2Cu+S	79.2
CADMIUM.	Cd	55.8	sulphuret,	Cu+S	47.6
oxide,	Cd+O	63.8	FLUORINE.	F	18.68
chloride,	Cd+Cl	91.25	GLUCINUM	G	17.7
sulphuret,	Cd+S	71.8	oxide (glucina)	G+O	25.7
CALCIUM	Ca	20.5	GOLD	Au	200
oxide, (lime)	Ca+O	28.5	oxide,	Au+O	208
chloride,	Ca+Cl	55.95	teroxide,	Au+3O	224
sulphuret,	Ca+S	36.5	chloride,	Au+Cl	235.45
phosphuret,	Ca+P·	36.2	terchloride,	Au+3Cl	306.35
CARBON.	C	6	tersulphuret,	Au+3S	248
carbonic oxide,	C+O	14	HYDROGEN.	H	1
carbonic acid,	C+2O	22	protoxide(water)	H+O	9
chloride,	C+Cl	41.45	deutoxide,	H+2O	17
perchloride,	2C+3Cl	118.35	hydrochloric		
hydruret,	2C+2H	14	acid,	H+Cl	36.45
bihydruret,	C+2H	8	hydrobromic		
bisulphuret,	C+2S	38	acid,	H+Br	79.26

Names of Substances.	Symbols.	Atom Wts.	Names of Substances.	Symbols.	Atom. Wts.
hydriodic acid,	H+I	127	NICKEL.	Ni	29.5
hydrofluoric acid,	H+F	19.68	oxide,	Ni+O	37.5
			sesquioxide,	Ni+1½O	41.5
IODINE.	I	126	chloride,	Ni+Cl	64.95
iodic acid,	I+5O	166	sulphuret,	Ni+S	45.5
chloriodic acid,	I+2Cl	196.90	NITROGEN.	N	14
IRIDIUM.	Ir	98.6	protoxide,	N+O	22
IRON.	Fe	28	deutoxide,	N+2O	30
oxide,	Fe+O	36	hyponitrous acid,	N+3O	38
peroxide,	Fe+1½O	40			
chloride,	Fe+Cl	63.45	nitrous acid,	N+4O	46
perchloride,	Fe+1½Cl	81.22	nitric acid,	N+5O	54
sulphuret,	Fe+S	44	chloride,	N+4Cl	155.8
bisulphuret,	Fe+2S	60	iodide,	N+31	392
LEAD.	Pb	103.5	bicarburet (cya-		
oxide,	Pb+O	111.5	nogen,	N+2C	26
sesquioxide,	Pb+1½O	115.5	OXYGEN.	O	8
peroxide,	Pb+2O	119.5	OSMIUM.	Os	99
chloride,	Pb+Cl	138.95	oxide,	Os+O	107
iodide,	Pb+I	229.5	PALLADIUM.	Pd	53
sulphuret,	Pb+S	119.5	oxide,	Pd+O	61
LITHIUM.	L	10	deutoxide,	Pd+2O	69
oxide, (lithia)	L+O	18	PHOSPHORUS.	P	15.7
chloride,	L+Cl	45.45	hypophospho-		
sulphuret,	L+S	26	rus acid,	2P+O	39.4
MAGNESIUM. . . .	Mg	12.7	phosphorus acid	P+1½O	27.7
oxide(magnesia)	Mg+O	20.7	phosphoric		
chloride,	Mg+Cl	48.15	acid,		
MANGANESE. . . .	Mn	27.7	pyrophosphor-	P+2½O	35.7
oxide,	Mn+O	35.7	ic acid,		
sesquioxide,	Mn+1½O	39.7	chloride,	P+1½Cl	68.87
deutoxide,	Mn+2O	43.7	perchloride,	P+2½Cl	101.32
red oxide,	3Mn+4O	115.1	hydruret,	P+H	16.7 ?
varvacite,	4Mn+7O	166.8	bihydruret,	P+2H	17.7
chloride,	Mn+Cl	63.15	PLATINUM.	Pt	98.6
perchloride,	2Mn+7Cl	303.55	oxide,	Pt+O	106.6
sulphuret,	Mn+S	43.7	deutoxide,	Pt+2O	114.6
MERCURY.	Hg	200	chloride,	Pt+Cl	134.05
oxide,	Hg+O	208	bichloride,	Pt+2Cl	169.5
deutoxide,	Hg+2O	216	sulphuret,	Pt+S	111.6
chloride,	Hg+Cl	235.45	POTASSIUM.	Po	39.15
bichloride,	Hg+2Cl	270.9	protoxide, (po-		
iodide,	Hg+I	326	tassa,)	Po+O	47.15
deutiodide,	Hg+2I	452	peroxide,	Po+3O	63.15
sulphuret,	Hg+S	216	chloride,	Po+Cl	74.6
bisulphuret,	Hg+2S	232	iodide,	Po+I	165.15
MOLYBDENUM. . . .	Mo	47.7	sulphuret,	Po+S	55.15
oxide,	Mo+O	55.7	RHODIUM.	R	52
deutoxide,	Mo+2O	63.7	oxide,	R+O	60
bisulphuret,	Mo+2S	79.7	sesquioxide,	R+1 O	64
tersulphuret	Mo+3S	95.7	SELENIUM.	Se	40

Names of Substances.	Symbols.	Atom Wts.	Names of Substances.	Symbols.	Atom. Wts.
oxide,	Se+O	48	THORIUM,	Th	59.6
selenious acid,	Se+2O	56	oxide,	Th+O	67.6
selenic acid,	Se+3O	64	TIN,	St	57.9
SILICIUM,	Si	7.5	oxide,	St+O	65.9
oxide, (silica)	Si+O	15.5	deutoxide,	St+2O	73.9
SILVER,	Ag	108	chloride,	St+Cl	93.35
oxide,	Ag+O	116	bichloride,	St+2Cl	128.8
chloride,	Ag+Cl	143.45	sulphuret,	St+S	73.9
iodide,	Ag+I	234	bisulphuret,	St+2S	89.9
sulphuret,	Ag+S	124	TITANIUM,	Ti	24.3
SODIUM,	So	23.3	oxide,	Ti+O	32.3
protoxide, (soda)	So+O	31.3	titanic acid,	Ti+2O	40.3
peroxide,	So+1½O	35.3	bichloride,	Ti+2Cl	95.2
chloride,	So+Cl	58.75	bisulphuret,	Ti+2S	56.3
iodide,	So+I	149.3	TUNGSTEN,	Tu	99.7
sulphuret,	So+S	39.3	oxide,	Tu+2O	115.7
STRONTIUM,	Sr	43.8	tungstic acid,	Tu+3O	123.7
oxide, (strontia)	Sr+O	51.8	URANIUM,	U	217
chloride,	Sr+Cl	79.25	oxide,	U+O	225
iodide,	Sr+I	169.8	peroxide,	U+1½O	227
sulphuret,	Sr+S	59.8	VANADIUM,	V	68.5
SULPHUR,	S	16	oxide,	V+O	76.5
hyposulphurous acid,	2S+2O	48	deutoxide,	V+2O	84.5
sulphurous acid,	S+2O	32	vanadic acid,	V+3O	92.5
hyposulphuric acid,	2S+5O	72	bichloride,	V+2Cl	139.4
sulphuric acid,	S+3O	40	terchloride,	V+3Cl	174.85
chloride,	S+Cl	51.45	bisulphuret,	V+2S	100.5
sulphuretted hydrogen,	S+H	17	tersulphuret,	V+3S	116.5
TELLURIUM,	Te	32.2	YTTRIUM,	Y	32.2
oxide,	Te+O	40.2	oxide, (yttria)	Y+O	40.2
chloride,	Te+Cl	67.65	ZINC,	Zn	32.5
bichloride,	Te+2Cl	103.1	oxide,	Zn+O	40.5
			chloride,	Zn+Cl	67.95
			sulphuret,	Zn+S	48.5
			ZIRCONIUM,	Z	30
			oxide, (zirconia)	Z+O	38

BAROMETER. An instrument, well known, for measuring the pressure of the atmosphere. It consists of a glass tube about thirty-six inches in length, closed at one end, which is filled with mercury freed from air, and inverted into a vessel containing the same liquid. See page 131.

BASE or BASIS. This term in chemistry signifies the opposite of an acid, and is extended to all those bodies which can neutralize the properties of acids and form salts with them. In the alkalies and alkaline earths, these neutralizing powers exist in the highest degree; they are less strong in the earths, and more feeble still in the metallic oxides properly so called; and the denomination is founded upon the consideration that the base is the characteristic principle of the salts. *Basic*, sometimes employed in speaking of a salt, expresses that it contains an excess of base; and in speaking of an oxide, that it can pro-

duce salts in combination with the acids. The difference between the terms *base* and *radical*, is that the former is employed for opposition to the acids, and the latter for the combustible bodies, for opposition to oxygen. Thus potash is the base in nitrate of potash, but potassium is the radical of potash.

BLOWPIPE. This is an instrument by means of which the flame of a candle or lamp, can easily be converted into a species Fig. 6. of furnace, capable of communicating an intense heat to small bodies placed in the flame, and consequently of being applied to many useful purposes. The operation consists in impelling from a small aperture, against the flame, a stream of air moved with velocity, by means of the organs of respiration and the mouth, or by a bellows. The blowpipe is an instrument which has been long employed in many of the arts, and is of extreme utility to the chemist. 1. Because most of the experiments which can be performed in the large way, may also be done with the blowpipe. 2. The experiments which in the large way require many hours, may in this method be finished in a few minutes. 3. The smallest particle of a substance is sufficient. The forms which have been given to this instrument, and the materials of which it is constructed, are very various. The common blowpipe is a long conical brass tube; two or three inches of the narrow end being bent, so that the termination is nearly at right angles to the other part of the instrument. In Fig. 7. consequence of the gradual condensation of moisture from the breath in the tube, when the instrument is much in use, a small portion of aqueous matter is sometimes ejected through the beak into the flame, and upon the substance to be heated. This occasions an irregular flame, and sometimes does harm to the heated substance ; and the blowpipe is therefore improved, by having a chamber constructed at one part of it for the reception of such moisture; the accumulated water being removed after the experiments are over. Dr. Black's blowpipe is a conical vessel, close except at the summit, to which the mouth is applied, and at a lateral aperture below, from which a small pipe proceeds, terminating in a nozzle or jet. This cone serves not merely to condense the moisture, but in a slight degree to regulate the pressure of the air forced through it by the lungs and mouth. Dr. Wollaston's instrument, on the contrary, has no chamber, but consists of Fig. 8. Fig. 9. two or three pieces of tube, which, when arranged together, form an excellent blowpipe, and when dismounted, pack into the size of a small pencilcase. For further descriptions of the blowpipe and directions concerning its use, the reader is referred to Faraday's chemical manipulation, and to Griffin's work on the blowpipe.

When a more intense heat is required than can be produced by the common blowpipe, the compound or oxy-hydrogen blowpipe may be employed. See page 117.

CALCINATION. A process which consists in the subjection of solid bodies to heat, so as to deprive them of some of their principles. Thus the calcination of chalk or limestone to convert them into lime, consists in driving off its carbonic acid and water. Most commonly it is applied to bodies which become oxidated by heat, and the term calcination was formerly synonymous with oxidation.

CALORIC. A term derived from the Latin *calor*, heat and used to designate the agent to which the phenomena of heat and combustion are applied.

CALORIC, *Latent*, is that portion of the fluid matter of heat which exists in any body without producing any effect upon another ; what produces an effect being termed *free* or *sensible caloric*. See page 36.

CALORIC, *Specific*. The relative proportion of caloric that any body retains without the effects being sensible ; its power of retention being called *capacity for caloric*. See page 60.

CALORIFIC RAYS, are those rays or emissions from the sun, or any burning body, which impart the sensation or other effects of heat.

CAPUT MORTUUM. A term employed by the Alchemists to designate what remains in the retort after a distillation. They compared this mass to a dead head, which the distillation has deprived of its spirit.

CAUSTICITY. All substances which have so strong a tendency to combine with the principles of organized substances as to destroy their texture, are said to be caustic. The principal of these are the concentrated acids, pure alkalies, and alkaline earths. To render caustic an alkali or an alkaline earth, is to separate from it the acid with which the body was combined under the form of a salt, (generally a carbonate,) and thus to bring it to the pure alkaline state.

CEMENTS. See LUTES.

COHESION, is that relation amongt he component particles of a body by which they are found to cling together, requiring more or less effort to force them asunder. See page 14.

COMBINATION. The intimate union of the particles of different substances by chemical attraction, so as to form a compound possessed of new and peculiar properties. See page 25.

COMBUSTIBLE. A body which, in its rapid union with others, causes a disengagement of heat and light. Combustibles may be either simple or compound.

COMBUSTION. The disengagement of heat and light which accompanies chemical action. See page 63.

COMPRESSIBILITY. That quality of a substance, whether solid or fluid, which allows it to be pressed, or rather squeezed, into a less bulk than it naturally occupies. The ultimate particles of all bodies are supposed to be incompressible.

CONCENTRATE. To render more strong: the term is employed when a dilute acid, a saline solution, &c. are deprived of more or less of the water which they contain. When we operate upon substances

which are less volatile than water, we concentrate them by evaporation; when upon those which are more volatile than water, we separate the water by distillation. Sometimes the water may be separated by congelation, the part remaining uncongealed becoming thus more highly concentrated. *Concentration* is therefore the opposite of *dilution*.

CONDENSE. This term is employed to designate an operation, the object of which is to cause a gas, or a vapour of the gaseous form, to assume the solid or the liquid state.

CONGELATION. The conversion of a liquid into a solid body by the abstraction of heat. Thus water when frozen is said to be congealed. See page 53.

CRUCIBLES. Pots of various sizes for subjecting bodies to heat. They are made either of earth, black-lead, forged iron, silver, or platinum; and each of these has its particular uses.

For ordinary purposes what are called Hessian crucibles, made of a mixture of clay and sand, will be found most convenient, as they resist a very high temperature and are not so apt to be fluxed when heated with saline substances. They have a triangular

Fig. 10.   Fig. 11.   Fig. 12.   Fig. 13.

form, and the annexed figures represent other forms.

Crucibles should never be exposed suddenly to either heat or cold, as they are very frequently cracked. When they are removed from a hot furnace they ought to be placed on a piece of charred wood or a few cinders kept for that purpose.

Black-lead crucibles are made of a mixture of plumbago and clay, and are much used in the arts. They are not so liable to crack as the Hessian crucibles, but they are destroyed by long exposure to a current of heated air, and by nitre and some other saline substances. Crucibles made of Wedgewood's ware are very compact, and should be placed in a common crucible when they are used, as they are apt to crack. Platinum crucibles will bear a very intense heat, and are not acted upon by any of the simple acids; they are therefore of great value in chemical analysis.

CUPEL. A small vessel made of calcined bones, or bone ashes, upon which we cupel silver with lead in the assaying furnace. It is prepared most easily by driving pounded bone ashes into a small brass or iron mould by means of a pestle forcibly struck by a wooden mallet. It must then be removed cautiously, placed on a piece of paper, and dried before using it. The mould is open above and below, and may be compared to the section of a tube with thick sides. The pestle is made so as to give the necessary depression.

Fig. 14.
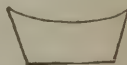
Fig. 15.

CYANOMETER. An instrument invented by Saussure, for comparing the different shades of blue.

Fig. 16.

DECANTATION. The pouring off the clearer part of a fluid after the substances which disturb its transparency are deposited at the bottom of the vessel. In order to pour a liquid from a large mouthed vessel into a small mouthed one, the following expedient is sometimes resorted to. Apply a little tallow to the edge of a large vessel, hold the middle of a glass rod against the tallow, and then, by inclining the large vessel, make the liquid run gently down the rod into a vessel placed below the point of the rod to receive it. The tallow prevents the liquor from running down the outside of the large vessel.
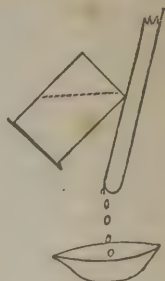
DECOCTION. A term used to designate a solution obtained by boiling a vegetable or animal substance with water.

DECOMPOSITION. The reduction of a body to its elementary principles.

DELIQUESCENCE. The conversion of saline and other solid bodies into liquids by exposure to the air, in consequence of the water which they attract from it. See page 16.

DENSITY. From the Latin *densitos*, closeness, is a relative term, and denotes the comparative quantity of matter in different bodies which is contained in the same space. Gravity is understood to act in proportion to the relative quantity of the matter of bodies; and hence the specific gravities of bodies are presumed to be the measure of their densities. See GRAVITY.

DEOXIDATION. The depriving a substance of the oxygen which it contains.

DETONATION. A sudden combustion and explosion.

DIGESTER. A strong vessel of iron or other metal, having a screwed down and air tight lid, into which animal or other substances are enclosed, immersed in water and submitted to a higher degree of heat than could be had in open vessels. By this contrivance the solvent power of the water is so much increased, that bones (so which it was originally invented) are converted into a jelly.

DISTILLATION. The vaporization and subsequent condensation of a liquid, by means of an alembic, a still, and refrigeratory, or of a retort and receiver. The apparatus represented on page 121 is frequently employed for this purpose in the laboratory.

Fig. 17.

The term distillation is often applied to the whole process of converting malt or other saccharine matter into spirits or alcohol. In such cases, a copper vessel and refrigeratory are usually employed.

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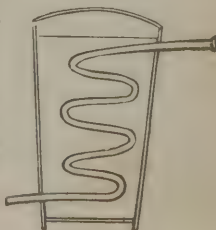
DUCTILITY. That property of bodies which renders it practicable to draw them out in length. The term is almost exclusively applied to the metals. See page 204.

DROPPING BOTTLE, or **EDULCORATOR.** This is a very useful instrument, which may be very easily constructed by passing a small glass tube into a cork and inserting this into a phial capable of receiving it, distilled water being put in as shown in the cut. The portion of air confined above the liquid, being expanded by the warmth of the hand, creates a pressure upon it, and expels it drop by drop, or in a stream, according as the position is perpendicular or horizontal. The water may be more forcibly discharged by blowing into the bottle, and then suddenly inverting it.

Fig. 18.

EFFERVESENCE. The commotion produced in liquids by some part of the mass suddenly taking the elastic form and escaping in numerous bubbles.

EFFLORESCENCE. The change which takes place in a salt when it becomes spontaneously converted into a dry powder. It is occasioned by the loss of water of crystallization. See page 16.

ELASTICITY. This term, derived from a Greek word signifying *to push*, or drive back, denotes that quality of a substance, whether solid or fluid, by which when compressed, or when forcibly expanded, it endeavours in either case to re-assume its former bulk.

ELECTROMETER. An instrument used for ascertaining the quantity and quality of the electricity in an electrified body. See page 76.

ELECTROPHORUS. An apparatus which is often used for transmitting an electric spark through gaseous mixtures. It consists of a resinous cake and of a conductor in which the electricity is collected. The resinous cake is prepared by melting together equal weights of common resin, shellac and Venice turpentine, and pouring the compound while still hot upon a metallic plate or marble slab. It should be placed upon a metallic plate and struck lightly with a piece of warm flannel or of fur, when required for use. The conductor, which may be made of a piece of thin wood covered with tin foil, and provided with a glass handle, is to be placed upon the resinous cake, touched with the finger while in this position, and removed by the glass handle ; it will now be charged with electricity, and on bringing any substance near it, a spark will be given off which may be transmitted through the gaseous mixture to be subjected to its action. This operation is usually performed in Volta's or Ure's Eudiometer.

Fig. 19.

ELECTROSCOPE. An instrument for exhibiting the attractive and repulsive agencies of electricity. See page 76.

EMPYREUMATIC. An expression which is employed in speaking of the products of the dry distillation of organic substances.

EUDIOMETER. An instrument for determining the proportion

of oxygen in a given quantity of atmospheric air, or other gaseous mixtures of which oxygen is one of the constituents. See pages 133 and 136.

Fig. 20.

Volta's eudiometer is made of a stout glass tube with two copper or platinum wires fixed into it near the top, where it is closed, and approaching till they are at a very little distance from each other within it. The mixture to be detonated (which is made by adding hydrogen gas to the gas to be examined), is then introduced into the eudiometer over water or mercury, as may be necessary, keeping it in an upright position, and wiping the upper part to remove any adhering liquid. On connecting one of the wires with the ground by a chain, or touching it with the finger, and bringing the tube near the charged conductor of the electrophones, or of the electrical machine, an electric spark will be immediately transmitted through the mixture, passing between the terminations of the wires within the tube, and causing it to explode. One of the wires should terminate in a brass ball without the eudiometer, that a larger spark may be drawn from the conductor than can be obtained from the wire alone. If it be required to examine any of the resulting products, the tube should not be filled more than one third full, and depressed in the liquid to prevent any of the contents being thrown out.

Dr. Ure's eudiometer is more convenient than Volta's for detonating small quantities of inflammable mixtures by means of the electric spark. It consists of a bent tube, closed at one end, with wires fixed into it in the usual manner. The mixture is introduced after filling with mercury, when the greater portion of the liquid still remaining in the open extremity of the tube is poured out; it is then placed in the position represented in the cut. Then close the open end with the thumb, which is to be placed so as to touch one of the balls; charge the conductor, and apply it to the other end. The gaseous mixture at the top expands as the spark passes through it, and presses upon the mercury below, forcing a portion of it into the other extremity of the tube, where the air acts as a spring, and moderates the violence of the explosion. It is necessary to leave as much mercury in the open extremity as will completely fill the other, should a complete condensation accompany the detonation.

Fig. 21.
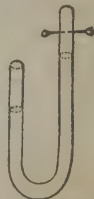
Should the spark not be sufficiently strong to inflame the mixture, a larger quantity of electricity may be collected in the Leyden jar, by charging the conductor of the electrophorus repeatedly and bringing it into contact with the ball at the top. See page 133.

EVAPORATION. A chemical operation performed upon a solution by means of which those parts which can be converted into vapour are driven off and the solid matter remains behind; it may be performed in a glass

Fig. 22.   Fig. 23.
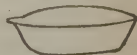
or Wedgewood ware dish, and the heat, especially towards the close of the operation, should be cautiously regulated. The best mode of applying the heat is by means of a sand or water bath.

EXPANSIBILITY. That property of a substance which renders

it capable, under certain circumstances, of occupying more space than it usually requires. The grand agent in the expansion of bodies is *caloric*.

EXPLOSION. A sudden and instantaneous combustion of combustible gases or of solid substances ; as a mixture of hydrogen and oxygen gases, gunpowder, fulminating powder, &c.

FILTRATION. This is an operation by which a fluid is mechanically separated from solid matters which are merely mixed with it. The apparatus fitted up for this purpose is called a filter. Sometimes the filtration is effected by a piece of tow, cotton or sponge, stuffed into the pipe of the funnel. Sand, pulverized glass, flints, porous stones, earthen ware, and many other substances, are also occasionally used for the same purpose. But unsized paper or white blotting paper, is almost exclusively employed in the laboratory. It should be so strong that a single filter of it capacious enough to hold a pint of water, will not break with that quantity, even though some degree of agitation be given to the funnel containing it; and it should be so porous as to allow clean water to run in a considerable stream.

The simplest mode of preparing a paper filter, is as follows. Take a round piece of white blotting paper, fold it in half, so as to bring the point a upon the point b ; then fold it again so to bring the point c upon d, as in Fig. 25, and finally open the first fold so as to produce an inverted hollow cone, as in Fig. 26. The letter o points out the position of the centre of the paper in all the figures. The paper thus prepared is to be placed in a glass or porcelain funnel, which should be as nearly as possible of the same shape. It should not project above the funnel ; and previous to the filtration of the liquor, the filter should be washed with distilled water.

Fig. 24.

Fig. 25.   Fig. 26.

The passage of the fluid is sometimes retarded by the close adhesion of the filter to the funnel over the greater part of its surface. To obviate this difficulty various contrivances have been recommended, such as putting small glass rods or straws into the funnel before the filter is introduced, so as to lie down and against the sides. Ribbed funnels are recommended for the same purpose ; but the best expedient is to fold the filter so that the ribs may exist in the paper itself, which may be done by folding the filter so as to resemble a paper fan, and which when opened has the form represented in the figure. (*For particular directions see Faraday's Chemical Manipulation.*)
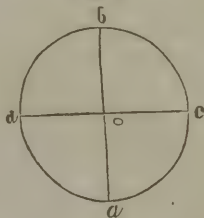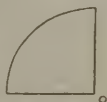
Fig. 27.

In conducting the filtration, care should be taken that the liquor does not rise quite to the top of the paper filter, otherwise it will escape between the paper and the glass, and then run down into the clear liquor, and render it necessary to repeat the operation. The neck of the funnel may be placed in the ring of a retort stand or through a hole made in the middle of a thin board. A filtering stand represented in the figure is a very convenient and useful piece of apparatus.
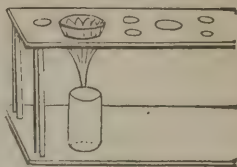
Fig. 28.

FLUX. This term is applied to certain fusible substances used in metallurgic operations, which combine with and remove the foreign bodies which prevent the union of melted metallic globules. We employ, as fluxes, carbonate of potash, (called *white flux* when it is prepared with equal parts of nitre and salt of tartar; and *black flux* when it is prepared with one part of the first and two of the second,) fluor spar, glass, &c.

FUSIBILITY. That property by which bodies assume the fluid state.

FUSION. The act of fusing. Also the state of a fused body.

FURNACES. Instruments constantly used in the laboratory and in the arts for subjecting bodies to a high heat. There is scarcely any limit to the number of furnaces which have been contrived as particularly adapted either to special or general uses. For detailed descriptions of these I must refer to more extended treatises. I shall describe one, which, while it is cheap and portable, is exceedingly useful in the laboratory.

A black lead or earthen crucible is selected for this purpose about 10 or 12 inches high and 6 or 7 inches wide at the top within. A certain number of holes are pierced in it, by a gimlet or brad awl, and enlarged by a round rasp. The pot is now bound round with iron or copper wire, to strengthen and hold it together when it cracks, an effect which is sure to take place after it has been a few times heated. This wire should be carried round in three different places, and secured by notches made in the pot with the edge of a rasp, and the ends should then be twisted together. It is also convenient to have a handle to these furnaces, which may be attached as in the figure.

Fig. 29.

A moveable grate like that figured in the wood cut, makes this furnace complete for many operations. If it be required to heat a crucible, the grate should be of such a size as to drop into the furnace, and rest between the bottom and the second row of holes. The part below then forms the ash-pit to be supplied with air by the four holes; and the part above forms the body of the furnace to receive the fire and the crucible. If a shallow fire only is wanted, as in the process of distillation or the heating of tubes, the grate should be of such size as, when dropped into the furnace, to descend only a little below the first tier of holes, the ash-pit having two tiers of holes entering it.

Fig. 30.

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Half a dozen of these small grates will be required in the laboratory, for the purpose of fitting at different times into different parts of the same furnace, and also for use in different sized furnaces of the kind now described.

When we wish to diminish the intensity of the fire, the holes or a portion of them may be closed with soft brick or clay stoppers. On the contrary, when it is desirable to increase the temperature, or to increase the body of fuel, additions are made at the top of the furnace. A very useful one consists of the upper part of an old crucible cut off so as to form a ring, which should be bound round with wire, as was directed in regard to the furnace.

Fig. 31.

A most useful accompaniment to these small portable furnaces, is a piece of straight funnel-pipe, about two feet long, four inches in width, and opening out below until it is about eight inches in diameter. This will easily rest upon any furnace not more than eight inches nor less than four or five inches wide; is quickly put on or off; stands steadily of itself, and increases the draught powerfully. A wooden handle may be attached to it for convenience; or without it, the tongs will serve to remove it. It may either be taken off when the fire requires to be made up, or the pieces of charcoal may be dropped in from above. There is no difficulty in raising a crucible two inches and a half in diameter to a white heat, by a furnace of this kind, and that in any situation which may be convenient, upon the tables or the floor, and with all the advantage of arranging or dismounting the apparatus with extreme facility.

Fig. 32.

For a more detailed description of this furnace, see Faraday's work on chemical manipulation, from which the above account has been abridged. This author states that the ignitings and heatings which belong to the analysis of siliceous and other minerals, have long been made in furnaces of this kind, at the Royal institution.

GALVANIC CIRCLE. If between two plates of different metals, a fluid be interposed which has a chemical effect on one of the metals, and little or none on the other; and if a communication be made between other parts of the plates by means of a conducting substance, (as a wire,) a continued current of electricity will be produced through the conductor, from one plate to the other, as long as the chemical action is exerted. This is a simple *galvanic circle.* If a number of similar pairs of plates, be placed alternately with an acting fluid intervening between each, and the two ends of the series connected by a wire, it multiplies the effect, and is called a *galvanic* or *voltaic pile* or *battery.* See page 80.
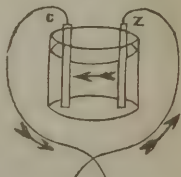
Fig. 33.

GAS. A term adopted by modern chemists to denote permanent æriform (or airlike) fluids generally, for the purpose of distinguishing them more clearly from common air, which is a mixture of two kinds of gas. A gas retains its elasticity in all ordinary temperatures, and in this it differs from a vapour.

GRANULATION. The process of reducing a very fusible metal to small grains. To effect this object, the melted metal is poured into a wooden box, the interior of which is covered with chalk, and then agitating the box until the metal is cold. It is then reduced to grains, of which the smallest may be separated by a sieve.

GRAVITY, *relative and specific.* The comparative or relative gravities of different bodies towards the earth are measured by a general standard called *weight,* and one substance is said to have a greater *specific gravity* than another, when a less portion of its bulk is of equal weight to that other. Thus, a cubic inch of platinum is nearly twice the weight of a cubic inch of silver; and therefore, is said to have double its *specific* gravity—the *specific* gravity of platinum, *relative* to that of silver, is as two to one. In this mode of comparison, the gravities are relative; but a standard is assumed with which both may be compared. That standard, for solids and liquids, is water, which is reckoned unity, and compared with that fluid, silver is 10·5 and platinum 21·4 ; that is, equal bulks of water, silver and platinum, would have weights in these proportions. In designating the specific gravities of gases, the standard, or unity, is atmospheric air.

Mode of determining the specific gravity of solids. If the solid is heavier than water, first weigh it in air ; then weigh it in water by a balance in the manner represented in the figure, suspended by a very fine silk thread or horse hair from the bottom of one of the scales. The difference in the results will express the weight of a quantity of water equal in bulk to the solid whose specific gravity is to be determined, and the following proportion will give its specific gravity in relation to water. As the weight of the water equal in bulk to that of

Fig. 34.

the solid, is to the weight of the solid itself, so is the specific gravity. Thus :—

If the solid weigh 100 grains in air, and 60 grains in water, then 100—60, or 40 : 100 : : 1 : 2·5. The specific gravity of the solid is therefore 2·5 compared with that of water.

In determining the specific gravity of solids lighter than water, we attach to the light solid by a slender thread a heavy body, the specific gravity of which has been previously ascertained. Then weigh them together in water, and from the difference between their weight in water and their weight in air, subtract the difference between the weight of the heavy solid in air and its weight in water ; the remainder shows the weight of a quantity of water equal in bulk to the light body, and the specific gravity can then be ascertained in the way directed above. Thus if the weight of the light solid be 10 and of the heavy solid 20 ; and if the weight of the heavy solid in water be 18, of the two together 7 ; then—
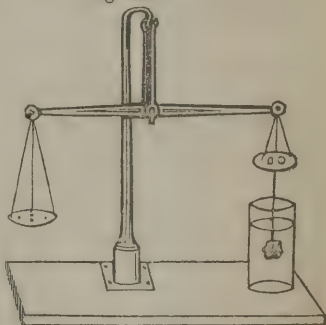
From their weight in air -   -   -   -   20+10=30
Subtract their weight in water   -   -   -   7
                                                              ———
                                                               23
And from this subtract 20—18=2   -   -   -   2
                                                              ———
The remainder   -   -   -   -   -   -   - 21

expresses the weight of a quantity of water equal in bulk to the light solid;—and the following proportion will give us its specific gravity :—

$$21 : 10 : : 1 : 0.47619,—$$

the specific gravity of the lighter solid.

Specific gravity of Liquids.

Take a bottle of known weight, fill it with distilled water, and weigh it carefully ; then pour out the water, and after drying the bottle, fill it with the liquid to be tried. The following proportion will give its specific gravity : As the weight of the distilled water, is to the weight of the liquid, so is 1 to the specific gravity required. Suppose the weight of the distilled water be 300 grains and that of the liquid 600, the following are the proportions :—

$$300 : 600 : : 1 : 2.$$

Specific gravity of Gases.

Atmospheric air is taken as the standard of comparison in estimating the specific gravity of gases. The first step of the process is to determine the weight of a given volume of air, which may be done by weighing a light glass flask furnished with a good stop-cock, while full of air, and then weighing it a second time after the air has been withdrawn by means of the air pump. The difference between the weights gives the information required. The weight of any gas may be determined by a similar method. Suppose 100 cubic inches of oxygen gas to weigh 34·109 grains, the weight of the same quantity of pure and dry atmospheric air being 31·0117, the specific gravity of the oxygen may be thus deduced ; as 31·0117 : 34.109 : : 1. (sp. gr. of air) : 1.1025 the specific gravity of oxygen.

In taking the specific gravity of the gases, particular regard should be had to the purity of the gas and to its hygrometric condition, as well as to the pressure and temperature of the air.—*From Reid's Practical Chemistry.*

TABLE *of the Specific Gravities of various bodies, alphabetically arranged.*

Body	Sp. Gr.
Acid, Acetic	1.062
Arsenic,	3.391
Arsenious,	3.728
Benzoic,	0.667
Boracic, crystallized,	1.479
do. fused	1.803
Citric,	1.034
Formic,	1.116
Muriatic,	1.200
Nitric,	1.271
do. highly concentrated,	1.583
Phosphoric liquid,	1.558
do solid,	2.800
Sulphuric,	1.850
Alcohol, absolute	0.797
do highly rectified,	0.809
do of commerce,	0.835
Alum,	1.714
Amber, *from* 1.065 *to*	1.100
Amianthus, *from* 1.000 *to*	2.313
Ammonia, aqueous	0.875
Arragonite,	2.900
Barytes, sulphate *from* 4.000 *to*	4.865
do carbonate of *from* 4.100 *to*	4.600
Basalt, *from* 2.421 *to*	3.000
Beryl, oriental	3.549
Blood, human	1.053
do crassamentum of	1.215
do *Serum of*	1.030
Borax,	1.714
Caoutchouc or India Rubber	0.933
Chalk, *from* 2.252 *to*	2.657
Coals, *from* 1.020 *to*	1.300
Copal,	1.015
Copal, red *from* 2.630 *to*	2.857
Corundum,	3.710
Cider,	1.018
Diamond, oriental colourless	3.521
Dolomite, *from* 2.540 *to*	2.830
Dragon's blood (a resin)	1.204
Ether, Acetic	0.866
do Muriatic,	0.729
do Nitric,	0.908
do Sulphuric *from* 0.632 *to*	0.775
Emerald, *from* 2.600 *to*	2.770
Fat of beef,	0.923
Felspar, *from* 2.438 *to*	2.700
Gamboge	1.222
Garnet, precious *from* 4.000 *to*	4.230
Gases, Atmospheric air	1.000
Ammoniacal,	0.590
Carbonic acid,	1.527
Carbonic oxide,	0.972
Carburetted hydrogen	0.970
Chlorine,	2.500
Cyanogen,	1.805
Hydriodic acid,	4.340
Hydrogen,	0.069
Muriatic acid,	1.284
Nitric oxide,	1.041
Nitrogen,	0.972
Nitrous oxide,	1.527
Oxygen,	1.111
Phosphuretted hydrogen,	0.902
Prussic acid,	0.937
Sulphuretted hydrogen	1.180
Sulphurous acid,	2.222
Glass, crown,	2.520
Green,	2.612
Flint, *from* 2.760 *to*	3.000
Plate,	2.942
Granite, *from* 2.613 *to*	2.956
Gum arabic,	1.452
Gunpowder, loose	0.836
Gypsum, compact, *from* 1.872 *to*	2.288
Honey,	1.450
Hornblende common, *from* 3.250 *to*	3.830
Jasper, *from* 2.358 *to*	2.816
Jet,	1.300
Indigo,	1.009
Isinglass,	1.111
Ivory,	1.825
Lead glance or Galena, *from* 6.565 *to*	7.786
Magnesia, native, Hydrate of	2.330
do Carbonate of *from* 2.220 *to*	2.612
Malachite, compact *from* 3.572 *to*	3.994
Marble, Carrara,	2.71
White Italian,	2.707
Black veined,	2.704
Parian,	2.560
Metals—Antimony,	6.702

Metals—Arsenic,	5.763	Expressed—Codfish,	0.923
Bismuth,	9.880	Linseed,	0.940
Brass, *from* 7.824 *to*	8.396	Olives,	0.915
Cadmium,	8.600	Rapeseed,	0.913
Chromium,	5.900	Whale,	0.923
Cobalt,	8.600	Opium,	1.336
Columbium,	5.600	Orpiment, *from* 3.048 *to*	3.500
Copper,	8.900	Pearl, oriental, *from* 2.510 *to*	2.750
Gold, cast	19.25	Peat, *from* 0.600 *to*	1.329
do hammered	19.35	Phosphorus,	1.770
Iridium, hammered	23.00	Porcelain from China,	2.384
Iron cast at Carron	7.248	do Sevres,	2.145
Lead,	11.35	Proof spirit,	0.923
Manganese,	8.000	Rock crystal, *from* 2.581 *to*	2.888
Mercury, solid 8°	15.61	Rock salt,	2.143
Below 0 of Fahr.	1	Sapphire, oriental, *from* 4.000	
do at 32° of Fahr.	13.61	*to*	4.200
do at 60° of Fahr.	13.58	Spar fluor, *from* 3.094 *to*	3.791
do at 212° of Fahr.	13.37	do Calcareous, *from* 2.620 *to*	2.837
Molybdenum,	8.600	Spermaceti,	0.943
Nickel, cast	8.279	Steam of water,	0.481
do forged	8.666	Sugar,	1.606
Osmium and Rhodium,		Sulphur, native	2.033
alloy of	19.50	Tallow,	0.941
Palladium,	11.80	Topaz, *from* 4.010 *to*	4.061
Platinum,	21.47	Tourmaline, *from* 3.086 *to*	3.362
Potassium, at 59° F.	0.865	Turquoise, *from* 2.500 *to*	3.000
Rhodium,	10.65	Ultramarine,	2.360
Selenium,	4.300	Vinegar, *from* 1.013 *to*	1.080
Silver,	10.47	Water, distilled	1.000
do hammered,	10.51	Tea,	1.028
Sodium, at 59° F.	0.972	Water of the Dead sea	1.240
Steel, soft	7.833	Wax, bees,	0.964
tempered,	7.816	White,	0.968
hardened,	7.840	Wine—Burgundy,	0.991
tempered and har-		Malaga,	1.022
dened,	7.818	Port,	0.997
Tellurium, *from* 5.700 *to* 6.115		White champagne,	0.997
Tin, Cornish	7.291	Wood—Apple tree,	0.793
Tungsten,	17.40	Ash,	0.845
Uranium,	9.000	Beech,	0.852
Zinc, *from* 6.900 *to*	7.191	Box, French,	0.912
Mica, *from* 2.650 *to*	2.934	Brazilian, Red	1.031
Milk,	1.032	Campeachy,	0.913
Naptha, *from* 0.700 *to*	0.847	Cedar, Wild	0.596
Oils, essential—Amber,	0.868	American,	0.561
Aniseseed,	0.986	Cherry tree,	0.715
Carraway seed,	0.904	Cork,	0.240
Cinnamon,	1.043	Ebony, American,	1.331
Cloves,	1.036	Elm tree,	0.671
Lavender,	0.894	Hazel,	0.600
Mint,	0.898	Lignum Vitæ,	1.333
Turpentine,	0.870	Linden tree,	0.604
Expressed—Sweet almonds,	0.932	Mahogany,	1.063

Wood, Maple tree,	0.750	Wood, Poplar tree,	0.383
Oak heart, 60 years old	1.170	Walnut,	0.681
Olive tree,	0.927	Willow,	0.585
Plum tree,	0.785	Zircon, *from* 4.385 *to*	4.700

HOMOGENEOUS. (From the Greek *homos*, alike, and *genos*, kind) designates such substances as have their particles all of the same nature, and consequently possessing the same properties. *Heterogeneous*, on the contrary, (Greek *heteros* different) denotes that the substance which it denominates is made up of parts that have different qualities. Thus in minerals, the diamond is a *homogeneous*, and granite is a *heterogeneous* body.

HYDRATES. Chemical compounds, particularly salts, which contain water as one of their ingredients, have been termed *hydrates*. If water is not a constituent, they are said to be anhydrous; a Greek compound which signifies *without water*.

HYDROMETER. Synonymous with areometer, which see.

HYDROUS. Watery, or containing water in its composition.

HYGROMETER. An instrument employed to measure the relative quantity of moisture which exists, at any particular time and place, in the atmosphere.

INDUCTION. That effect of an *insulated* electrified body which tends to produce an opposite electric state in neighbouring bodies. See page 74.

INSULATION. When a body containing a quantity of free caloric, or of electric fluid, is surrounded by non-conductors, so as to cut off the communication with other bodies, it is said to be insulated; a metaphor taken from the Latin *insula*, an island.

KELP. Incinerated sea weed.

LABORATORY. A place properly fitted up for the performance of chemical operations.

LAMPS. These are instruments of great use in the laboratory, being very economical and ready sources of heat. And as flame possesses a very high temperature, the heat of a lamp may be rendered quite intense. For chemical purposes the most useful lamp is that in which alcohol is burned. The great advantage of this material is that it produces no smoke or fuliginous matter. Spirit lamps are of various forms and sizes; depending upon the particular use to which they are to be applied. A very powerful and useful lamp, frequently supplying the place of a furnace, is formed by making an aperture of 0.8 or 0.9 of

Fig. 35.

an inch by 1¼ through the body of the lamp, and fixing in it four burners, upon Count Rumford's principle, each of a length equal to the width of the aperture, and the 1-8 or 1-16 of an inch wide. These are to be parallel to each other, and at such distances as to have five spaces or air ways, the two outer being half the width of the inner. These burners rise about a quarter of an inch above the lamp, and descend as low as the bottom of the body, being fastened in the aperture by their edges. Each burner is closed beneath, but has a small hole in-

to the lamp as a passage for the alcohol, thus forming as it were a part of the lamp. The lamp is supported upon four balls about half an inch in diameter, to allow of the access of air beneath and up the apertures to the flame. The alcohol is introduced by a hole in the upper surface of the lamp, which is usually closed by a screw; and the burners are trimmed by putting down each a double cotton of on Argand lamp until it touches the bottom, and then cutting it off about the eighth of an inch above the top. This lamp becomes still more effectual in heating a crucible when assisted by a chimney.—*Faraday's Chem. Emanip.*
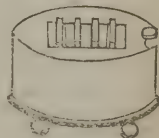
A very cheap and useful lamp may be easily made as fol- Fig. 36.
lows. Take a piece of glass tube, and by a file cut off two or three inches in length, make a hole through a cork with a hot wire and enlarge it with a rattail file, and pass the tube through till it projects at the upper end about an inch. Then select a wide mouthed bottle and fit the cork and tube into it. The wick of the lamp, made of threads of cotton wick, is to pass through the tube, and dip into the spirit below. To prevent the evaporation of the spirit when the lamp is not in use, cut off the sealed end of a test tube of such diameter and length as to cover the tube and wick and rest on the cork. When the lamp is burning, the cork should be loosened, otherwise the spirit will not properly rise.

LEYDEN PHIAL or JAR. The *Leyden Phial* or *Ley-* Fig. 37.
den Jar (so called because it was first constructed in that city) is a cylindrical glass vessel, coated to a certain height, inside and outside, with some conducting substance, which is capable of being charged with electrical fluid accumulated for various experiments. A combination of such phials is an *electrical battery.*

LIQUEFACTION. The conversion of a solid into a liquid, either by the agency of heat or of water. See page 53.

LIXIVIATION. The application of water to the fixed residues of bodies, for the purpose of extracting the saline part.

LIXIVIUM. A solution obtained by lixiviation.

LUTE. A substance used to close the joinings of vessels. Lutes are of various kinds, depending upon the nature of the process, and of the substances to be distilled.

When mere watery vapours are to be contained, it will be sufficient to cover the joinings of the apparatus with slips of paper, or linen covered with flour paste, or of wet bladder. In other cases a lute made of quick-lime slaked in the air and beaten into a liquid paste with whites of eggs may be employed. And when acid or corrosive vapours are to be contained, we must have recourse to the *fat lute,* which is made by moistening with water some finely powdered clay, and then beating this paste well in a mortar with boiled linseed oil.

A good gas lute may be prepared by heating together one part of wax and three of lard. When pieces of apparatus are to be permanently join-

ed a cement may be employed, which is prepared by melting together four parts of resin, and one part of bees wax mixed with one part of brick dust.

Bees wax melted with one eighth part of common turpentine forms a valuable cement for fixing glass tubes into retorts or bottles, not to be exposed to the action of corrosive liquids. It may be made into sticks like sealing wax, melting and spreading it with a hot iron when required for use. It is less brittle than common sealing wax, and by using a larger portion of turpentine, a soft cement may be obtained, very useful for closing bottles accurately that contain substances which must not be exposed to the action of the air.

Plaster of paris is also used as a lute or cement. For this purpose the best method is to take a small quantity of water, and pour the plaster upon it till it shall have absorbed it all; it is then to be stirred, and in a short time it will begin to set. By mixing it up with gum water, or solution of glue, instead of water, it may be kept for a longer time before it begins to set.

For coating glass vessels so as to enable them to bear a red heat, a mixture of dry sand, powdered clay, and cut thread, is to be made into a stiff tenacious paste with water, using no more clay than is necessary to make the sand adhere, and mixing the cut thread with the other materials before adding any water. The paste is then to be put equally round the retort, and allowed to dry slowly for two or three days, heating it eventually in an open fire before it is used. Thin iron wire wrapped round the coating, serves to bind it together when it becomes hot, the whole being rubbed over afterwards with a portion of the mixture of sand and clay.

MACERATION. The steeping of a body in a cold liquor.

MATRASS. A name applied to glass vessels having the form here represented. They are employed as receivers in distillations, and they are made use of in all experiments where it is necessary to boil liquids. They are sometimes constructed in the form of Fig. 38, when they answer better as receivers. But when they are intended for boil-

Fig. 38. Fig. 39. Fig. 40. Fig. 41.

ing liquids, the more preferable form is that of Fig. 39. The form Fig. 40, though quite common, is inconvenient for solutions, because when the mass is to be removed a part of the matter not dissolved remains near the commencement of the neck, which should especially be avoided in an analysis.
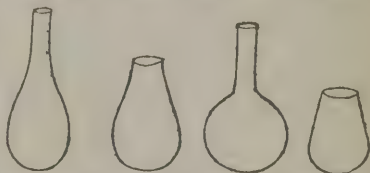
These vessels should be made of very thin glass and of uniform thickness. When they are placed upon the sand-bath they may be covered with a watch glass properly adjusted; and when the belly is a little larger than the mouth they answer very well even though the liquid, which is boiled, be violently agitated. In such a vessel also the portions which are not dissolved can be easily removed and thrown upon the filter.

The oil bottle or Florence flask may in many cases be substituted for the matrass.

Fig. 42.

MELTING POINT. That point of the thermometer which indicates the heat at which any particular solid becomes liquid, is termed the *melting point* of that solid.

MENSTRUUM. A word synonymous with solvent.

MERCURIAL TROUGH. An apparatus for the collection of such gases as are absorbed by water, made like the water trough, but much smaller. It may be made of wood, marble or cast iron ; when the latter is employed, it should be varnished, to prevent it from rusting.

MINERALIZER. Metallic substances are said to be mineralized when deprived of their usual properties by combination with some other substance. Thus iron is mineralized by sulphur in iron pyrites or bisulphuret of iron. See page 205.

MOLECULE. A diminutive, formed from the Latin *moles*, a mass, and denotes one of the minute particles of which the mass or body is composed. Molecules differ from atoms in this, that they are never considered but as portions of some aggregate.

MORDANT. A term employed in the art of dyeing to designate a liquor which gives to a fabric the property of fixing the dye stuff. It also usually modifies the colour. See page 414.

MORTARS. Instruments employed for the mechanical division of solid bodies. They are of various kinds, depending upon the particular uses to which they are to be applied. Thus a large iron mortar with a pestle of the same material is useful for breaking large lumps into smaller, and for the pulverization of ores, metals, and heavy coarse materials. The mortars made of Wedgewood ware when of good quality answer well for various purposes. The pestle should be of one piece ; if the handle is of wood and the bottom only of ware, the cement by which it is fastened occasionally falls out and produces injury to the materials in the mortar.

Fig. 43.   Fig. 44.

Fig. 45.   Fig. 46.

For the reduction of hard bodies to powder, porphyry or agate mortars are to be employed. These are hard and resist ordinary chemical action; but they cannot be obtained of large size, and are expensive, from the difficulty of making them out of a solid block. They should be used only for the pulverization and mixture of small portions of matter, and should not be inconsiderately subjected to blows. Pre-

Fig. 47.   Fig. 48.

vious to using them they should be roughened by means of the pestle and a little emery or sharp sand.

Glass mortars are too soft and brittle to be of any use in the laboratory.

NEUTRALIZATION. When an alkaline liquid is added to an acid liquid in a certain proportion, the mixture has no effect on the colour either of litmus or turmeric. The mixture is then said to be *neutralized*.

OPACITY, (from the Latin *opacus*, dark.) A state impervious to light.

OXIDATION. The process of converting metals or other substances into oxides by combining with them a certain portion of oxygen. It differs from acidification in the addition of oxygen not being sufficient to form an acid with the substance oxidized.

PHENOMENON, (plural *Phenomena*.) A Greek word, signifying an *appearance*, and is limited in our language to denote the appearances in nature, whether discovered by direct observation or experiment, for which there is no obvious cause. An *hypothesis* is an assumed cause, by which we endeavour to account for a particular class of phenomena; and that hypothesis is best which solves the greatest number.

PHOTOMETER, (Greek *phos*, light, and *metron*, a measure,) is an instrument for measuring the different intensities of light. See page 70.

PIPETTE. An instrument, of the form here rep- Fig. 49. Fig. 50. resented, for conveying small quantities of a liquid from one vessel to another. It consists of a tube of glass with a bulb of about an inch in diameter in the middle, and a fine point at the end. It is used by putting the narrow point into the liquid and then sucking the liquid into the bulb with the mouth. The upper orifice of the tube is then closed with the tongue, the point of the tube removed into the proper vessel, and then by opening the upper end of the tube, the liquid runs out. The tube is sometimes bent as in the accompanying figure, because this form enables us the better to see when the bulb begins to be filled.
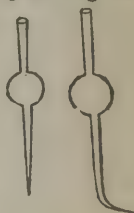
PRECIPITATE. When two limpid solu- Fig. 51. Fig. 52. tions are mingled together, and chemical action is excited, the whole mixture often becomes turbid, and a solid powder, in a state of extreme division, falls to the bottom of the vessel. This powder is called a *precipitate*, the agent employed expressly to produce it is called a *precipitant*, and the operation which causes its production is called *precipitation*. The vessels which are most suitable for this purpose are those which grow gradually narrower towards the upper part, because in these the precipitate is not so apt to adhere to the sides, and it all collects again at the bottom.

PRESSURE. The application of force to a resisting body, when that force is in continual contact with the body upon which it is exerted.

PULVERIZE. To reduce to powder. See *Mortars*.

PYROMETER. An instrument for measuring high degrees of heat. See page 52.

RAREFACTION. The act of causing a substance to become less dense; it also denominates the state of this lessened density. The term is more particularly applicable to elastic fluids, which expand so as to fill the vessel in which they are contained after part is extracted. The gas becomes *rarefied* in consequence of the partial exhaustion. Liquids are expanded by means of heat, and thence become *thinner*, or more *rarefied*.

REAGENT. This name is applied to a body when it possesses the property of producing, with another, a determinate phenomenon by means of which we can distinguish it from other bodies. Thus, for example, a drop of infusion of nut-galls allowed to fall into a liquid containing iron, gives to this last a black colour, which denotes the presence of iron. The infusion of galls is then a reagent for the iron.

RECEIVER. This is a chemical vessel which is adapted to the neck or beak of retorts, alembics, and other distillatory vessels, to collect, receive, and contain the products of distillation. Fig. 53 is a plain, and Fig. 54 a tubulated, receiver.

Fig. 53.   Fig. 54.
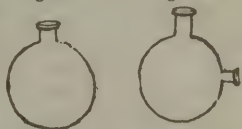
RECTIFY. A pharmaceutical term, which means to purify or concentrate by distillation.

REDUCTION. The process of separating oxygen from an oxide to bring it to the primitive state of a combustible body. Also applied to the separation of the bases from chlorides, sulphurets, &c. See page 206.

REFRACTORY. A body is so called which resists, without melting, the highest heat of our furnaces.

REGULUS. A metal reduced and united by fusion into a mass.

RETORT. This is a kind of vessel employed for many distillations, and most frequently for those which require a degree of heat superior to that of boiling water. It is a kind of bottle with a long neck, so bent that it makes with the belly of the retort an angle of about sixty degrees. It is probable that retorts have received their name from this form. The most capacious part of the retort is called its belly. Its upper part is called the arch or roof of the retort, and the bent part is

Fig. 55.   Fig. 56.

the neck. Retorts are either plain, or tubulated, that is, having an opening in the arch, and they are made of glass, porcelain, iron, and platinum. Glass retorts in most common use vary in capacity from two ounces to a pint. The cast iron mercurial bottle or a gun-barrel may

be used as substitutes for the iron retort. Platinum retorts are employed in the distillation of the acids.

ROASTING. In a chemical sense, the roasting of a metallic sulphuret or arseniuret, is to heat it to redness in contact of the air, to drive off the sulphur or the arsenic, and to obtain the metal in the state of an oxide. In the arts this word is also applied generally to the calcination to which all the ores of iron are subjected before they are melted in a high furnace.

SAFETY VALVE. A necessary appendage to a steam engine ; being a valve opening outwards from a boiler, and loaded with a weight sufficient to withstand the pressure of the steam until it rises to a required height ; but which would be forced open before the steam could burst the boiler.

SALIFIABLE BASES. The alkalies and those earths and metallic oxides which have the power of neutralizing acidity entirely or in part and producing salts.

SATURATION. When two bodies combine with each other until the one cannot take up an additional quantity of the other, the first is said to be *saturated.*

SEPARATOR. See *Syphon.*

SOLUTION. The nature of this process is explained on page 22. A variety of vessels are used for performing this operation. Of these the most useful is the Florence, or oil flask, which being made of thin glass, bears the sudden application of heat without breaking. (See Matrass.) A solution can be readily boiled

Fig. 57.

in a flask over a lamp or charcoal fire. Wedgewood ware capsules from two to six inches in diameter and furnished with a lip, Fig. 58. are also very useful vessels for solution and evaporation. The following figure represents a vessel of great value not only for solutions but for many other chemical operations. It is a simple glass cylinder without foot or rim, or ornaments of any kind. Tumblers, or what are called by druggists specie bottles, frequently answer the purpose. But a glass less thick at the bottom is to be preferred, because it is less liable to break when exposed to heat.

Fig. 58.
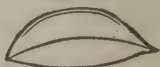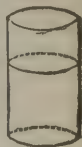
SPATULA. A kind of knife which is very useful in transferring small quantities of powder from place to place, as, for example, into and out of the balance ; one of platinum, for this and other purposes, is requisite in every laboratory. It may be about half an inch wide, at least three inches long, and so thick as to resist considerable force without bending. A pocket knife with a platinum blade answers many of the purposes of the spatula above described. For the removal of powders, ivory or bone spatulas may be employed.

Fig. 59.
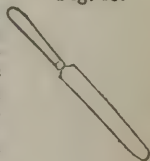
SPECIFIC GRAVITY. See *Gravity, specific.*

STEAM. This term is generally applied to the visible cloudy vapour arising from water, and which at low temperatures is supposed to be the consequence of a chemical solution of water in air ; but steam, as

39*

it is used in the arts, denotes water in an elastic form, at or above the temperature of the boiling point, when it is invisible. See page 57.

SUBLIMATION. This is a process by which volatile substances are raised by heat, and again condensed in the solid form. The apparatus for performing this operation is very simple; a Fig. 60. matrass or small alembic being generally sufficient for the sublimation of small quantities of matter. In many cases, two crucibles may be employed for the same purpose, as in the sublimation of metallic arsenic from a mixture of arsenious acid and black flux. The mixture must be put into a larger crucible, which may be placed in a sand bath and exposed to a strong heat, inverting the other crucible and luting it to the first; a small aperture must be left at the edge for the escape of gaseous matter, or, a hole may be bored in the smaller crucible, and a glass tube inserted in it.

SYNTHESIS. The combination of two or more bodies of different kinds into a chemical compound. It is the inverse of *analysis*.

SYPHON. This instrument is used in the laboratory for Fig. 61. the purpose of removing a clear liquid from a precipitate. It is merely a bent tube, which is previously filled with water or any other liquid; and on introducing the shorter limb into the vessel containing the liquid to be drawn off and under its surface, it will rise in the syphon and pass out by the other extremity.
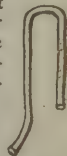
A useful vessel for the separation of a small quantity of valuable fluid may be made of a piece of glass tube from a third   Fig. 62. to a quarter of an inch in diameter, by drawing it out in one part until it becomes capillary, and turning it up as in the figure. The point *a* must be closed in the flame of the spirit lamp, the mixed fluids poured into the tube, and suffered to remain till separated. The point *a* is then to be broken off so as to open an aperture, and then by inclining the instrument, first one fluid and afterwards the other, may be decanted. The fluids will issue drop by drop into the vessels placed to receive them, and the surface of contact of the two in the fine tube is so small, that scarcely an appreciable portion of the valuable one need be wasted. The pouring, or transference rather, is more steady and regular when the beak *a* is placed against the side of the receiving vessel, so that no drop is formed, but a continuous minute stream.—*Faraday.*

Glass syringes are also very advantageous in the removal and separation of fluid. Such a one as that here figured, may be used in some cases. The tow wrapped round the wire which forms the piston, is made sufficiently tight by being moistened with water; and when not inconvenient, a little water may be retained both above and below it.

Fig. 63.
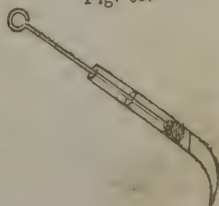
TEMPERATURE. A definite degree of sensible heat, as measured by the thermometer.

TEST. In chemistry, any reagent, which added to a substance teaches us to distinguish its chemical nature or composition.

TESTING. The liquid to be tested should be put into a small wine glass or one of the test tubes described below. A few drops only of the liquid are to be employed; and the tests, which are usually liquid, must be added in very small quantity. Sometimes it will be sufficient to dip the end of a clean glass rod into the test, and then stir the liquid with it. Flat plates of glass or porcelain are useful where very small quantities of a liquid are to be tested. White paper may be used for the same purpose, and the liquids may be tested by means of glass rods or camel's hair pencils.

THERMOMETER. An instrument for measuring degrees of heat. See page 50.

TUBE APPARATUS. A great number of chemical operations may be performed with apparatus constructed either partly or altogether of glass tube of half an inch in diameter, or less, and of different degrees of thickness. This tube may be cut into such lengths as are required by a three-cornered file; and a table blowpipe, mouth blowpipe, or even a large spirit lamp, will afford a sufficient degree of heat for working them into such forms as may be desired.

In addition to these, the operator should have a number Fig. 64. of tubes closed at one end, of various diameters, and of all lengths from one inch to five or six. They should be well annealed at the closed end, and widened a little at the other, which is open.

A test tube of this kind may be used for performing on a small scale all those experiments in which a glass vessel is required, such as a flask or a precipitate glass. In general, it is better not to fill it more than one third or one fourth full, when it is necessary to apply heat. The test tube may also be used as a subliming apparatus, or as a small pneumatic jar.

The following figure represents a tube with a bulb blown at one end so as to constitute a small matrass. Glasses of Fig. 65. this kind may be used when a substance is to be heated over a lamp with a view to ascertain whether it contains water, which, if present in the solid matter, is sublimed, and condensed on the inner surface of the narrow part of the tube.
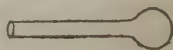
For introducing small portions of fluid into a tube, a plain Fig. 66.
tube funnel may be easily made by holding the middle of a
piece of tube of the same kind as the common test-tube in the
flame of a lamp till it becomes soft; when, after turning it round
in the flame so that the heat may be applied as equally as pos-
sible, it is removed, and the extremities pulled gently away
from each other. A much smaller tube is thus formed in the
middle, and on dividing it, two tube funnels are procured.

Tube apparatus is frequently employed for
distilling small portions of liquid, or in pre-
paring small quantities of some of the gases.
A piece of tube sealed at one end, and then
bent as in the figure, forms what is called a
tube retort; a receiver for it being made of a
piece of straight tube of larger diameter closed
at one end.

Fig. 67.

When a larger tube retort is required,
it is often useful to draw out and contract
the neck for the purpose of diminishing
its capacity, and consequently the quan-
tity of vapour which it can contain; a
common narrow-necked phial then makes
an excellent receiver.

Fig. 68.

The following is a very useful form of tube
where a small quantity of gas is disengaged.
If the sealed end be filled with dilute muriatic
acid, and a fragment of marble be then thrown
in, the manner in which it is used will be seen
by holding it in the position represented in the

Fig. 69.

figure. None of the carbonic acid escapes; it is all collected in the
sealed extremity of the tube, and may then be transferred to another
apparatus, filling the open end of the tube previously with water or
mercury.

A convenient form of condensing tube for
heavy vapours, or easily fusible substances,
as iodine, naphthaline, &c. is that of the an-
nexed figure, the bent tube being of such di-
ameter as freely to pass over the subliming
tube, but not larger. The condensation
takes place principally in the middle portion
of the tube, and the refrigeration may be effected most conveniently by
moist paper or immersion in water.

Fig. 70.

Berzelius recommends on some occasions the use of an open tube for
sublimation, the length being about six
inches, the diameter half an inch or more,
and the position an inclined one. When a
substance is heated in the lower part of the
tube, an upward current of air carries the
vapours forward into the cooler part, where,
if condensable under the existing temperature and circumstances, they

Fig. 71.
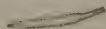
assume the solid or liquid form. The air has access to such a tube, or it may be shut out by the finger at pleasure, and any combustible body heated in it may consequently be burnt if required.

The evaporation of a large quantity of water from Fig. 72. tubes upon the sand bath is usually a very slow one, unless some expedient is employed to facilitate its entrance and its exit. A very convenient one is to insert one end of an open bent tube, as in the figure; a current of air is thus established either in one direction or the other, and the aqueous vapour readily removed. A more convenient evaporator is a bent tube open at both ends, which being set in the sand-bath or otherwise heated, so as to have one limb rather hotter than the other, has a current spon- Fig. 73. taneously established through it. The evaporation proceeds with readiness and facility; the dry results are very easy of excess, and yet little danger of their dispersion during the process is incurred.
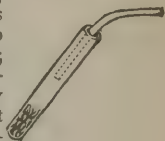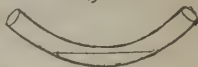
A very convenient mercurial receiver of the form here rep- Fig. 74. resented may be made of tube from half to three quarters of an inch in diameter, and from four to ten inches in length. It is closed above, but open at the lower extremity. It is to be filled with mercury when inclined, by pouring in the metal at the mouth, and is then to be suspended or supported in the position represented, with an evaporating basin containing mercury beneath it. The small tube delivering gas is to be introduced at the mouth, so far as to allow the bubbles to pass into the tube, and the mercury to flow out in the basin below. When the mercury has descended nearly to the flexure, the operation should be stopped.

With an apparatus of this kind and a small quantity of mercury, many of the properties of the gases may be easily examined without the help of any other tube. For details concerning its use, see *Faraday's Chemical Manipulation.*

A minute apparatus resembling Woulf's may be easily formed of a piece of tube one third or one half an   Fig. 75. inch in width, bent as in the figure. The gas should be passed in at one end, and will bubble through the water in the lower flexures, and if soluble will form solutions. If it be required that the gas should come into contact with a large surface of water, one of the lower bends should be extended in a horizontal position.

TUBULURE. This name is applied to the aperture in the belly of a retort or matrass. These vessels are then said to be *tubulated.*

VAPOUR. Any liquid expanded into an elastic, or gaseous fluid, by means of heat. It differs from gas in its want of permanency; for it returns into the liquid state, when exposed to a diminished temperature.

VOLUME. The apparent space which a body occupies is termed its *volume* ; the *effective* space which the same body occupies, or its real bulk of mass, is its *mass* ; the relation of the *mass* to its *volume*, (or the quotient of the one by the other,) is its density ; and the empty spaces or voids which render the volume larger than the mass, are its *pores.*

TABLE *showing the Proportions in which several Gaseous Bodies combine by Volume.* [*From Dr. Henry's Chemistry.*]

Names of Substances.		Volumes of Elements.	Resulting Volumes.
Protoxide of chlorine, gas	1	oxygen+2 chlorine	2½
Peroxide of chlorine, gas	2	oxygen+1 chlorine	2
Chloric acid, vapour	2	oxygen+1 chlorine	
Iodic acid	2½	oxygen+1 iodine	
Aqueous vapour, steam	1	oxygen+2 hydrogen	2
Muriatic acid, gas	1	chlorine+1 hydrogen	2
Hydriodic acid, gas	1	iodine+1 hydrogen	2
Nitrous oxide, gas	½	oxygen+1 nitrogen	1
Nitric oxide, gas	1	oxygen+1 nitrogen	2
Hyponitrous acid, vapour	1½	oxygen+1 nitrogen	1
Nitrous acid, vapour	2	oxygen+1 nitrogen	1
Nitric acid, vapour	2½	oxygen+1 nitrogen	1
Atmospheric air	1	oxygen+4 nitrogen	5
Ammonia	3	hydrogen+1 nitrogen	2
Muriate of ammonia	1	muriatic acid+1 ammonia (solid)	
Sulphurous acid, gas	1	oxygen+1 sulphur	1
Sulphuric acid, vapour	1	oxygen+2 sulphurous acid	2
Sulphuretted hydrogen, gas	1	hydrogen+1 sulphur	1
Phosphuretted hydrogen, gas	1½	hydrogen+½ phosphorus	1
Perphosphuretted hydrogen, gas	1½	hydrogen+¾ phosphorus	1
Carbonic oxide, gas	½	oxygen+1 vapour of carbon	1
Carbonic acid, gas	1	oxygen+1 vapour of carbon	1
Carbonic acid	½	oxygen+1 carbonic oxide	1
Carbonate of ammonia	1	carb. acid+2 ammonia (solid)	
Sesquicarbonate of ammonia	1	carb. acid+1½ ammonia (solid)	
Bicarbonate of ammonia	1	carb. acid+1 ammonia (solid)	
Chlorocarbonic acid, gas	1	carbonic oxide+1 chlorine	1
Olefiant gas	2	hydrogen+2 carbon	1
Carburetted hydrogen, gas	2	hydrogen+1 carbon	1
Chloric ether, vapour	1	chlorine+1 olefiant gas	
Cyanogen, gas	1	nitrogen+2 carbon	1
Chlorocyanic acid, vapour	1	chlorine+1 cyanogen	2
Hydrocyanic acid, vapour	1	hydrogen+1 cyanogen	
Sulphuret of carbon, vapour	2	sulphur+1 carbon	1
Alcohol, vapour	1	olefiant gas+1 aqueous vapour	1
Muriatic ether, vapour	1	mur. acid, gas+2 alcohol	1
Sulphurous ether, vapour	1	olefiant gas+1 aqueous vapour	1

WEATHER GLASS. The barometer is popularly termed a weather glass, because its variations are commonly believed to prognosticate the approaching state of the weather. In former times the same appellation was given to the thermometer.

WEIGHT. The comparative measure of the gravity of bodies at the earth's surface.

TABLES *of Weights and Measures.* [*From Reid's Practical Chemistry.*]

Weights.

The Standard according to which the present system of English weights is regulated, is the Troy Brass Pound made in 1758. It contains 5760 Grains.

English Imperial Standard Troy Weight.

```
24 Grains       = 1 Pennyweight.
20 Pennyweights = 1 Ounce.
12 Ounces       = 1 Pound.
```

Avoirdupois Weight.

The pound avoirdupois contains 7000 grains, each of which is equal to a Troy grain, being thus heavier than the Troy pound by 1240 grains.

```
 1 Drachm  = 27.34375 Grains.
16 Drachms = 1 Ounce          = 437.5.
16 Ounces  = 1 Pound          = 7000.
28 Pounds  = 1 Quarter        = 196000.
 4 Quarters = 1 Cwt. or 112lb. = 748000.
20 Cwt.    = 1 Ton            = 15.680.000.   :
```

Apothecaries Weight.

The pound in Apothecaries Weight is equal to the Troy Pound containing 5760 Grains, but is differently subdivided.

```
1 Pound  ℔ = 12 Ounces  = 5760 Grains.
1 Ounce  ℥ =  8 Drachms = 480.
1 Drachm ℨ =  3 Scruples = 60.
1 Scruple ℈ = 20 Grains  = 20.
```

French Decimal Weight.

```
Gramme       = 15.4063  Troy Grains.
Milligramme  =  0.0154
Centigramme  =  0.1540
Decigramme   =  1.5406
Gramme       = 15.4063
```

Measures.

The English Imperial Standard Gallon contains ten pounds Avoirdupois weight of distilled water, weighed in air at 62° Fahr. and 30° Barom., or 12lb. 1 ounce, 16 pennyweights and 16 grains Troy = 70.000 grains weight of distilled water. A cubic inch of distilled water weighs 252.458 grains in air, and the Imperial Gallon contains 277.274 Cubic Inches.

English Imperial Measure.

1 Quarter	= 8 Bushels.
1 Bushel	= 4 Pecks.
1 Peck	= 2 Gallons.
1 Gallon	= 4 Quarts.
1 Quart	= 2 Pints.

or

Distilled Water. Grains. Avoir. lb.		Cub. In.		Pint.		Quart.		Gall.		Peck.		Bush.
8.750	= 1.25	= 34.659	=	1								
17.500	= 2.5	= 69.318	=	2	=	1						
70.000	= 10.	= 277.274	=	8	=	4	=	1				
140.000	= 20.	= 554.548	=	16	=	8	=	2	=	1		
560.000	= 80.	= 2218.192	=	64	=	32	=	8	=	4	=	1

Apothecaries Measure.

The Gallon of the former Wine measure and of the present Apothecaries measure contains 58333.31 Grains weight of distilled water, or 231 Cubic Inches, the ratio to the Imperial Gallon being nearly as 5 to 6, or as 0.8331 to 1.

1 Gallon	= 8 Pints.
1 Pint	O = 16 Ounces.
1 Ounce	f ℥ = 8 Drachms.
1 Drachm	f ℨ = 60 Drops, or Minims.

or

Gall.		Pts.		Oz.		Drachms.		Minims.		Grains of distil. water.		Cub.In.
1	=	8	=	128	=	1024	=	61440	=	58333.31	=	231.
		1	=	16	=	128	=	7680	=	7291.66	=	28.8
				1	=	8	=	480	=	455.72	=	1.8
						1	=	60	=	56.96	=	0.2

French Decimal Measure of Capacity.

Litre = 61.02525 British Cubic Inches, or 15406.312 grains of distilled water.

Millilitre =	0.06102 Cubic Inches.
Centilitre =	0.61025.
Decilitre =	6.10252.
Litre =	61.02525.

WOULF'S APPARATUS. So called from its inventor Woulf. It is composed of several tubulated bottles, and is used to conduct gases or to effect their absorption by liquids. The bottles are so arranged and put in communication with each other, as that the gas which is not absorbed by the water in the first passes into the second; that which is not absorbed by the liquid in the second passes to the third, and so on. Each bottle is provided

Fig. 76.
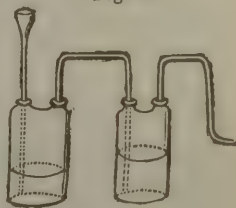
with three tubulures into which pass glass tubes which are fitted by passing through corks, and luting, and which conduct the gas from one bottle into the liquid in the next. The middle tube is a kind of safety tube ; the gas cannot escape through it, but if a condensation should occur in the bottle, the external air passes in by this tube, and prevents the liquid from one bottle passing into the other by absorption. The apparatus is rendered more manageable by cutting in two the tubes which connect the bottles and uniting them by short tubes of caoutchouc.

INDEX.

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ERRATA.

Page 60, 23d line from bottom, for " eqaul," read "equal."

Page 60, 14th line from top, for " murcury," read " mercury."

Page 108, 10th line from bottom, for " O+Cl," read " 4O+Cl."

Page 119, 14th line from top, in part of the edition for " protoxide of hydrogen on water," read " protoxide of hydrogen or water."

Page 163, 21st line from bottom, for " Hydrothionate," read " Hydrothionite."

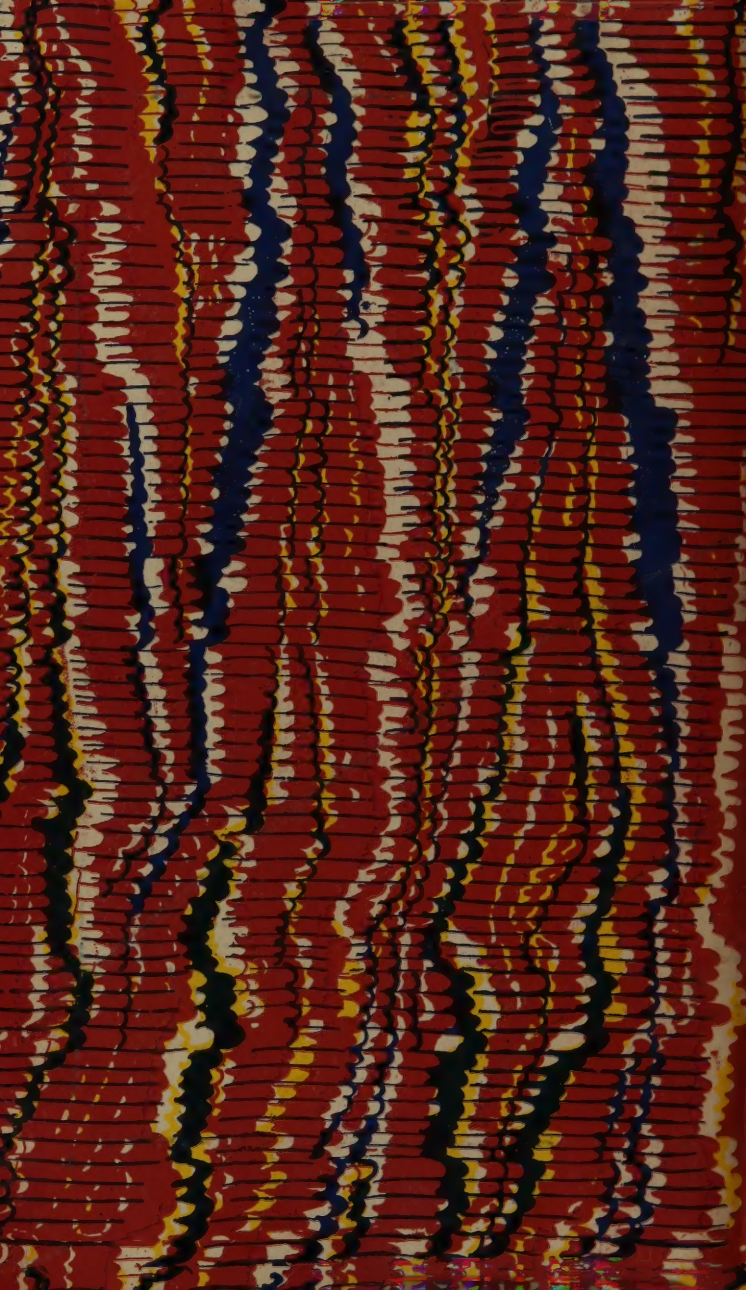Page 180, 25th line from top, for " chlorine and hydrogen," read " carbon and hydrogen."

Page 338,—The paragraph " crystallization of bismuth," should follow the " properties," of bismuth on page 337.

Page 379, 13th line from top, for " binoxolate," read " binoxalate."

Page 405, note, for " Raymond Sully," read " Ramond Lully."

Page 456, 9th line from top, for " Chem. Emanip." read " Chem. Manip."

Page 461. Plate 57 should be reversed.